Damascus Citizens for Sustainability

Oil gas drilling BRINE and CWT wastes and radioactivity that is not removed by the CWT

Upload of Volz Congressional testimony and Vengosh, Jackson followup and DCS 2011 Rubin report on the use (actually disposal) of drilling wastes on roads. AND Radioactivity in stream sediment paper, media and the papers published in 2012 and 2018.

The Volz and the Vengosh,Jackson papers both prove the existence of high concentration plumes of toxic materials from discharge from a Centralized Waste Treatment plant that was taking in liquid Marcellus drilling wastes for "treatment." The existence of elevated concentration plumes and the minimal nature of relatively unsupervised 'treatment' are both reasons why wastes from oil and gas drilling should not be allowed to be imported into the Delaware River Basin.

The plumes will impact fisheries, wildlife, humans swimming in the River and anyone or any community whose drinking water uptake is touched by a plume. There is not wholesale instantaneous mixing and 'dilution is the solution' does not apply for highly toxic or endocrine disrupting chemicals. The DRBC should not allow import of these wastes nor import of the outputs from facilities treating these wastes.

Besides truck accidents, there would also be illegal dumping of these materials in the Basin. There are toxic contaminants in these wastes, the impacts of which are described in the Rubin report. This report was prepared as a comment when in 2011, PA was pushing to allow statewide dumping on roads of oil and gas liquid drilling wastes, the state was calling "BRINE." That proposed PA statewide permit to dump was withdrawn as we hope the DRBC will withdraw the current proposal to import similar wastes.

There is a lot of radioactivity in these wastes. We are submitting the attached article from Environmental Science & Technology by Nathaniel Warner, et al. concerning levels of radium in river sediments downstream from the effluent discharge points of wastewater treatment facilities treating flowback and produced waters from HVHF wells completed in the Marcellus shale. This study documents radium levels in the downstream sediment approximately 200 times the upstream or "background" radium levels and greater than allowed radioactive waste disposal thresholds. The authors say, "The treatment facility "is supposed to prevent contamination of the environment, and I don't think it does."
and that "The treatment facility was adding water to the stream containing about 200,000 mg of salt per liter as well as metals and radioactive elements. In comparison, seawater has about 35,000 mg of salt per liter.
The vast excess of salt has created a dead zone stretching 500 meters downstream, Vengosh said."
There have been later papers verifying the high radioactivity in stream sediment - Jan, 2018 Dr. Vengosh says, "Despite the fact that conventional oil and gas wastewater is treated to reduce its radium content, we still found high levels of radioactive build-up in the stream sediments we sampled," Vengosh said. "Radium is attached to these sediments, and over time even a small amount of radium being discharged into a stream accumulates to generate high radioactivity in the stream sediments."

The Jan, 2018 follow-up paper (on page 11) says, "At all three investigated sites, we consistently find elevated Ra activities in stream sediments collected near effluent pipes at the outfall sites (226Ra = 57-14,949 Bq/kg; n= 26) compared to upstream sediments (226Ra = 9-41 Bq/kg; n=18)

(Figure 2).
and
Because Ra is significantly higher in sediments from disposal sites compared to sediments from upstream sites (up to ~650 times compared to the average 226Ra background activity at the Franklin Facility), combined with direct evidence for water contamination from OGW effluents in the stream water,20, 41 we suggest that the CWT facility discharges are the source for the elevated Ra in the impacted stream sediments. "
Paper is attached
Why we ask, would the DRBC want to import this waste to dispose of it in the Delaware River, whether it is pre or post treatment at a CWT?
The evidence is clear, we implore the Basin Commission to reject allowing, even as a possibility, the disposal in the Delaware River Basin of oil gas drilling wastes either with or without 'treatment' by Centralized Waste Treatment plants.

Environmental Science & Technology

Article

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Impacts of Shale Gas Wastewater Disposal on Water Quality in Western Pennsylvania

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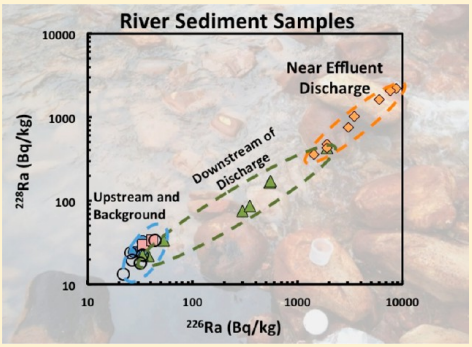
Supporting Information

ABSTRACT: The safe disposal of liquid wastes associated with oil and gas production in the United States is a major challenge given their large volumes and typically high levels of contaminants. In Pennsylvania, oil and gas wastewater is sometimes treated at brine treatment facilities and discharged to local streams. This study examined the water quality and isotopic compositions of discharged effluents, surface waters, and stream sediments associated with a treatment facility site in western Pennsylvania. The elevated levels of chloride and bromide, combined with the strontium, radium, oxygen, and hydrogen isotopic compositions of the effluents reflect the composition of Marcellus Shale produced waters. The discharge of the effluent from the treatment facility increased downstream concentrations of chloride and bromide above background levels. Barium and radium were substantially (>90%) reduced in the treated effluents compared to concentrations in Marcellus Shale produced waters. Nonetheless, ^{226}Ra levels in stream sediments (544−8759 Bq/kg) at the point of discharge were ∼200 times greater than upstream and background sediments (22−44 Bq/kg) and above radioactive waste disposal threshold regulations, posing potential environmental risks of radium bioaccumulation in localized areas of shale gas wastewater disposal.



INTRODUCTION

The safe disposal of large volumes of liquid waste associated with natural gas and oil production is a major challenge because the waste fluids often contain high levels of salinity, toxic metals, and radioactivity.[1−6] In the United States, oil and gas wastewater is managed through recycling of the wastewater for shale gas operations, injection into deep disposal wells, treatment in publicly owned treatment works (POTWs), wastewater treatment plants (WWTP), or commercially operated industrial wastewater treatment plants, and spreading on roads for dust suppression and deicing. Many of these disposal options are sometimes associated with environmental risks and are not available or allowed in some areas (e.g., lack of appropriate geology for deep-well injection sites or regulations that do not allow wastewater to be sprayed on roads or lands in most states). Oil and gas wastewater is composed of drilling fluids, hydraulic fracturing flowback fluids, and produced waters. Here we collectively define all of these fluids as residual wastewater.

In Pennsylvania, the overall estimated volume of oil and gas wastewater (3.1×10^6 to 3.8×10^6 cubic meters per year) has increased during recent years,[7,8] yet an increasing fraction of the wastewater is also reused.[7] In 2011, an estimated 70% of flowback and produced fluids were reused, and current operations aim to reuse more of the wastewater.[7] However, options for the proper disposal and management of the wastewater that is not recycled are limited, due to the poor water quality of flowback and produced waters. In 2011, ∼20% of drilling fluids, 8% of hydraulic fracturing flowback fluid, and 14% of produced water (i.e., brine) from unconventional Marcellus Shale wells were treated at centralized waste treatment facilities (treatment facilities) and then discharged to local streams.[7] The salinity of shale gas waste fluids varies from 5000 mg/L to >200 000 mg/L. This high-salinity water typically contains concentrated bromide, chloride, metals such as barium and strontium, and naturally occurring radioactive material (NORM) in the form of radium isotopes with activities of 185 to 592 Bq/L.[5] The elevated salinity and radioactivity in both flowback and produced waters reflect primarily the naturally occurring hypersaline brines that are associated with the formations targeted for natural gas production.[3,9]

Pennsylvania has historically managed wastewater from conventional oil and gas wells (i.e., vertical wells drilled into an oil/gas reservoir) by hauling it to industrial brine treatment facilities, which then discharge treated effluent to surface waters.[10] In 2010 there were 74 oil and gas water pollution control facilities, including both private brine treatment facilities and publicly owned treatment works (POTWs) permitted or awaiting permit approval to accept wastewater

Received: May 14, 2013
Revised: September 9, 2013
Accepted: September 10, 2013

dx.doi.org/10.1021/es402165b | Environ. Sci. Technol. XXXX, XXX, XXX−XXX

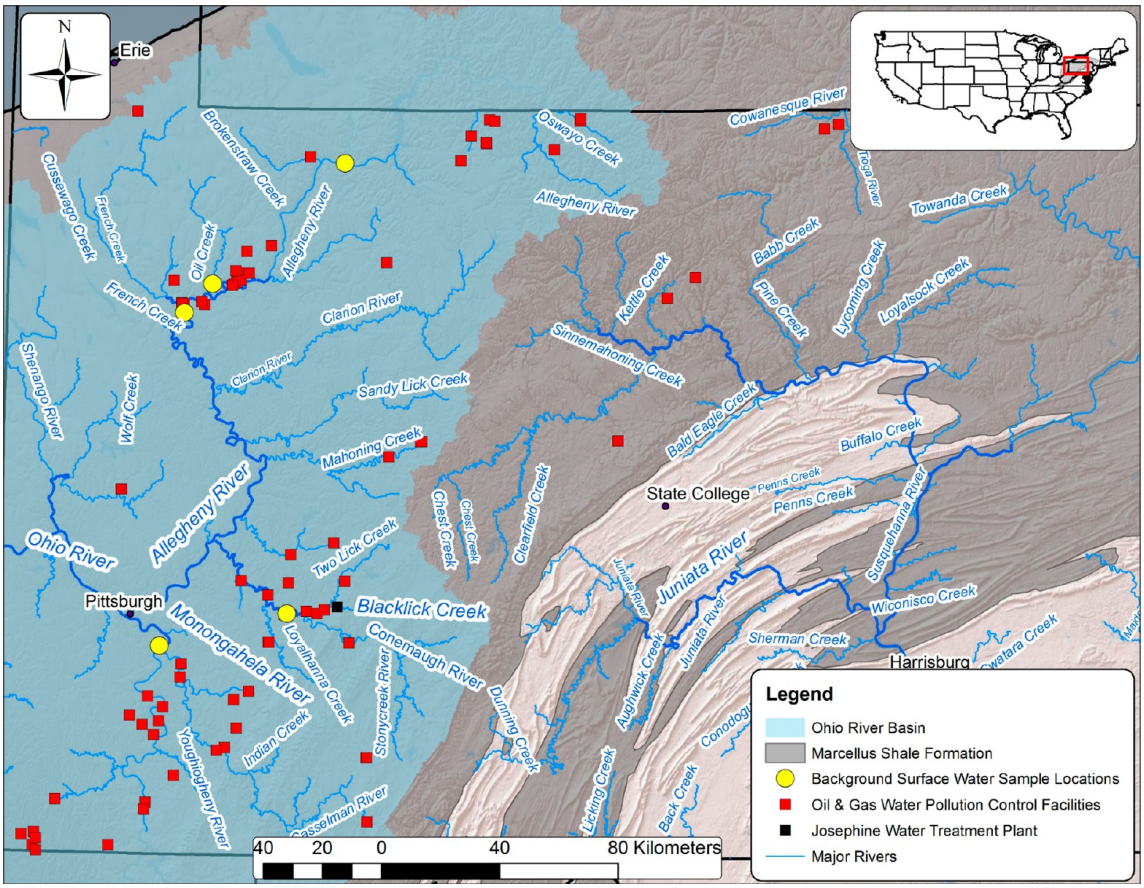


Figure 1. Map of the hydrological system of Pennsylvania and the locations of 74 facilities permitted in 2010 to accept and treat Marcellus Shale produced and flowback waters (red squares), the majority of which are located in the Ohio River Basin (light blue shading). This study focused on the Josephine Brine Treatment Facility (black square), a centralized waste treatment facility in western Pennsylvania where treated wastewater is discharged to Blacklick Creek (See SI Figure S1 for details). Background measurements (yellow circles) were collected in 2011 at locations upstream of any permitted facilities or >1 km downstream of permitted facilities.

in Pennsylvania (Figure 1; Supporting Information (SI) text).[10] Ferrar et al. (2013)[11] showed that treatment of wastewater by three of these facilities releases elevated concentrations of Cl, Br, Sr, and Ba to streams at concentrations above U.S. Environmental Protection Agency (USEPA) maximum contaminant levels, secondary maximum contaminant levels, criterion maximum concentrations, or criterion chronic concentrations.[11] The disposal of Marcellus wastewater through treatment facilities was also suggested to be linked to an overall increase of 5% in chloride concentrations at downstream surface water monitoring sites in western Pennsylvania[12] and likely increased the salt intake at downstream water treatment facilities.[6,13]

Veil (2010)[10] and Ferrar et al. (2013)[11] described in detail the treatment process of a brine treatment facility in western Pennsylvania, the Josephine Brine Treatment Facility, that exclusively treats oil and gas wastewater. Briefly, at the treatment facility the oil residual is skimmed off of the surface and Na_2SO_4 is added to remove salts and metals as a solid precipitate. The residual solid is then hauled to residual waste landfills.[11] Treated wastewater from the facility was released at a rate of ~0.585 million liters per day [MLd] (http://www.ahs.dep.state.pa.us/NRS/) to a stream with an average flow of 756 MLd.[14] During 2010 and 2011, a large portion (>50%) of wastewater treated in this facility was from the unconventional shale gas wells of the Marcellus Formation, but by September 2011 the amount of the Marcellus wastewater was reduced relative to produced water from conventional sources.[11]

In this study we analyzed the effluents that are discharged from the Josephine Brine Treatment Facility as well as streamwater and sediments, both upstream and downstream from the effluent discharge site along Blacklick Creek (Figure 1). We attempted to quantify the short- and long-term environmental impacts of shale gas wastewater disposal on surface water quality and stream sediments. We hypothesize that (1) the distinctive geochemical and isotopic fingerprints of the wastewater effluent would enable us to distinguish the contribution of unconventional Marcellus wastewater from conventional wastewaters, in spite of the treatment process; (2) mass-balance calculations could quantify the relative contribution of salts in the effluent to the receiving stream; and (3) stream sediment geochemistry would retain a record of the long-term impact of treated wastewater discharge in the local environment.

MATERIALS AND METHODS

We analyzed the concentrations of major constituents (Cl, Br, SO_4, Ca, Na, Mg, Ba, Sr), alkalinity, and isotopic ratios ($\delta^{18}O$, $\delta^{2}H$, $^{87}Sr/^{86}Sr$, and $^{228}Ra/^{226}Ra$) in effluents from the Josephine Brine Treatment Facility and in streamwater and

dx.doi.org/10.1021/es402165b | Environ. Sci. Technol. XXXX, XXX, XXX−XXX

Table 1. Summary of Means and Standard Deviation (SD) Values of the Chemical and Isotopic Data of Surface Waters and Effluents from the Josephine Brine Treatment Facility Discharge Site in Western Pennsylvania[a]

location	number of samples	distance downstream (m)	TDS calculated (mg/L)	Cl (mg/L)	Br (mg/L)	SO4 (mg/L)	alkalinity (mg/L)	Ca (mg/L)	Mg (mg/L)	Sr (mg/L)	Na (mg/L)	Ba (mg/L)	$^{87}Sr/^{86}Sr$	δ^2H	$\delta^{18}O$
AMD	3		454	19	0.09	409	na	89	25	0.48	11	0.04	0.71451	−59.4	−9.2
	SD		258	6	0.05	46		22	3	0.11	3	0.02	0.00005		
upstream	7	−50	209	18	0.05	152	8	39	11	0.19	21	1.32	0.71309	−49.9	−8.1
	SD	35	97	2	0.03	55	9	15	3	0.08	10	1.58	0.00007		
effluent	18	0	123453	80542	644	1099	254	12564	809	1388	27324	13.41	0.71056	−43.4	−4.1
	SD	0	27348	24058	201	621	10	3803	221	644	8288	6.29	0.00033	2.5	0.3
downstream (1−20 m)	6	10	7467	16214	138	252	26	873	78	73	1756	10.87	0.71063	−47.0	−8.0
	SD	9	3675	28919	251	85	8	334	26	25	880	13.31	0.00052		
downstream (20−300 m)	7	254	362	195	1.39	128	3	65	13	2.88	78	0.93	0.71146		
	SD	81	346	175	1.41	22	2	37	4	3.65	79	1.47	0.00142		
downstream (>300 m)	5	836	257	88	0.52	122	3	40	12	0.49	21	1.87	0.71182		
	SD	528	183	102	0.66	24		19	6	0.64	15	1.67	0.00134		
background	5		228	27	0.10	73	64	33	8	0.15	21	0.05	0.71321	−49.6	−7.9
	SD	na	133	9	0.08	87	22	19	6	0.13	14	0.02	0.00096	8.0	1.1

[a]The data are averaged over distances and years. The complete data set is presented in SI Table S1.

dx.doi.org/10.1021/es402165b | Environ. Sci. Technol. XXXX, XXX, XXX−XXX

sediments upstream and at different distances downstream of the discharge site along Blacklick Creek (SI Figure S1). Wastewater data were compared to background concentrations collected upstream of the facility, from other streams in western PA, and from published values for produced water and flowback from the Marcellus and other Appalachian Basin brines.[2−5]

Samples from the treatment facility site were collected during five field campaigns across a 2-year period beginning in August 2010 and continuing through November 2012. Eighteen effluent and 32 surface water samples were collected. Grab surface water samples were collected from 200 m upstream to 1780 m downstream of the effluent discharge from the treatment facility (SI Figure S1). Seven samples were collected in 2011 from other streams/rivers in western PA, including the Conemaugh, Alleghany, and Monongahela Rivers, in an effort to establish background concentrations and variability (Figure 1). On each sampling date, sample collection began with the downstream locations and proceeded upstream to avoid mobilizing sediments. In 2010, samples were collected across the width of Blacklick Creek near the facility outflow (SI Figure S1). Samples were field filtered (0.45 um) for analysis of cations, anions and strontium isotopes. Raw unfiltered samples were collected for alkalinity titration and oxygen and hydrogen isotopes. Following collection, all samples were stored on ice for transport to Duke University for analysis.

Major anions were determined by ion chromatography on a Dionex IC DX-2100 and major cations by direct current plasma optical emission spectrometry (DCP-OES) at Duke University. Alkalinity was determined in duplicate by titration with HCl to pH 4.5. Sr isotopes were prepared by total desiccation of sample aliquot containing approximately 3 μg of Sr. The dried sample was then digested in 3 N ultrapure HNO_3 and extracted on Eichrom Sr resin held in Teflon micro columns. The extracted Sr was then desiccated a second time and digested in TaCl solution before it was analyzed by thermal ionization mass spectrometer (TIMS) on a ThermoFisher Triton at Duke University. The average $^{87}Sr/^{86}Sr$ of the SRM-987 standard measured at Duke during this study was 0.710266 ±0.000005 (SD). Oxygen and hydrogen isotopes of water were determined by thermochemical elemental analysis/continuous flow isotope ratio mass spectrometry (TCEA-CFIRMS), using a Thermo-Finnigan TCEA and Delta+XL mass spectrometer at the Duke Environmental Isotope Laboratory (DEVIL). All measured isotopic values were normalized to Vienna Standard Mean Ocean Water (VSMOW).

A large volume (1−4 L) of treated wastewater was collected immediately before the discharge from the treatment facility entered the stream during two of the sampling campaigns in 2011 (SI Figure S1). The samples were filtered through a plastic column containing manganese-oxide covered acrylic fibers,[15] which efficiently adsorbed the radium isotopes. The fibers were transported to the Laboratory of Environmental RadioNuclides (LEARN) at Duke University. The fibers were then incubated in a sealed glass cylinder for 3 weeks to allow in-growth of ^{222}Rn (with a half-life of 3.85 days) and measured for ^{226}Ra using a Radon-in-Air monitor (RAD7, Durridge Inc.).[16] After determination of ^{226}Ra, the fibers were then crushed to achieve a uniform geometry packed and sealed in 90 mL tin cans. Their ^{228}Ra was measured by a Canberra DSA2000 broad energy germanium (BEGe) gamma detector.[17]

Grab sediment samples were also collected from the upper 5 cm interval over three separate sampling campaigns (2011−2012) (SI Figure S1). Approximately 100 g of sediment were scooped out of the stream with a plastic spatula and placed into 200 mL plastic sediment containers. Sediments were transferred and weighed in 90 mL tin cans and then dried in an oven at 50 °C for 24 h. The dried sediments were crushed to a diameter <5 mm using a mortar and pestle, weighed, and sealed in the can with electrical tape to prevent gas escape during incubations. The sealed cans were incubated for at least 3 weeks before each sample was counted on the gamma detector. ^{226}Ra activities were obtained through the 609 keV energy line of its decay product, ^{214}Bi, assuming secular equilibrium. ^{228}Ra activities were obtained through the 911 keV energy line. The activities of all nuclides were calibrated using CCRMP U−Th ore standard DL-1a measured under similar physical conditions (e.g., can geometry).

Statistical analysis was performed using STATA statistical software. Parameters were not normally distributed and therefore they were analyzed using a nonparametric rank sum analysis (Wilcoxon-Mann−Whitney).

RESULTS AND DISCUSSION

Characterization and Sources of the Wastewater Effluent. The concentrations of major elements (Cl, Br, Ca, Na, and Sr) in the treated wastewater effluent varied throughout the two-year sampling period, with levels up to 6,700 times higher than the concentrations measured in the upstream river sites (Table 1 and SI Table S1). For example, chloride concentrations in upstream Blacklick Creek and other upstream background sites were low (15−21 mg/L) throughout the study 2010−2012, whereas chloride in wastewater effluent concentrations ranged between 55 000 and 98 000 mg/L (about 2−5 times the concentration of seawater).

Major element concentrations (Cl and Br) of wastewater effluent were similar to the concentrations reported for produced and flowback waters from the Appalachian Basin (Table 2).[2−4,9,18] In addition, wastewater effluents had high Br/Cl ratios ($3−4 \times 10^3$), which characterize the Appalachian produced and flowback waters. This reflects the conservative behavior (i.e., not added or removed) of these elements throughout the treatment process. The concentrations of other nonconservative elements (e.g., Na, Ca, Sr, Ba) were more varied, which is consistent with previous findings (SI Table S1).[11] Sulfate was significantly ($p \ll 0.01$) enriched in the treated effluent relative to Marcellus flowback and produced waters, likely due to the addition of Na_2SO_4 during treatment (SI Table S2). In contrast, barium and radium contents in the effluents showed a significant ($p \ll 0.01$) average reduction of 99% (Table 2) relative to Marcellus flowback, indicating an effective removal during treatment.

The total activity of radium (i.e., $^{226}Ra + ^{228}Ra$) in wastewater effluent (^{226}Ra = 0.11 to 0.19 Bq/L and ^{228}Ra = 0.04 to 0.13 Bq/L; SI Table S3) was well below the industrial discharge limit of 2.2 Bq/L (60 pCi/L in the U.S). The total activities we measured were within the range of the radium values reported in May-June 2011 by the treatment facility to the USEPA (^{228}Ra range of zero to 0.74 Bq/L and ^{226}Ra range 0.05 to 3.24 Bq/L)[19] and similar to values reported by Pennsylvania Department of Environmental Protection for effluent at other brine treatment facilities in western Pennsylvania (http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/RadiationProtection/NORM.pdf). The $^{228}Ra/^{226}Ra$ ratio of the effluent sample we collected in August 2011 was 0.39, consistent with ratios reported for Marcellus flowback and produced water.[5] In June 2012, the $^{228}Ra/^{226}Ra$ ratio was 0.69,

Table 2. Comparison of the Mean Values of Major Elements and Selected Isotopic Ratios Reported for Brines from Upper Devonian Formations, Marcellus Flowback and Produced Waters, Brines from Lower Devonian or Older Formations, And Wastewater Effluent from the Josephine Brine Treatment Facility in Western PA[a]

mean values of produced water and flowback compared to discharge	TDS ppm	Cl ppm	Br ppm	SO_4 ppm	Ca ppm	Mg ppm	Sr ppm	Na ppm	Ba ppm	Ra-226 pCi/L	Ra-226 (Bq/L)	Ra-228 pCi/L	Ra-228 (Bq/L)	$^{87}Sr/^{86}Sr$	δ^2H	$\delta^{18}O$
[c]Upper Devonian	120 791	84 861	787	214	13 495	1920	586	34 150	332	700	26			0.71906	−41.25	−4.50
[c]Marcellus	93 170	69 516	744	21	9634	1056	1594	28 050	1692	3231	120	452	17	0.71119		
[b,c]Lower Devonian or Older	216 482	139 198	1283	222	23 766	2393	3491	55 625	1361	2739	101			0.71145	−40.47	−1.87
Effluent 2010−2012 (treated discharge)	98 899	81 771	643	1092	12,710	830	1363	27 670	13	4	0.15	2	0.09	0.71047	−44.14	−4.33

[a]Note that barium and radium are reduced in the effluent relative to Marcellus flowback waters. [b] - Only 2 measurements available. [c]Major element chemistry data from Dresel and Rose (2010) and Osborn and Mcintosh (2010). Strontium isotope values from Chapman et al (2012) and Osborn and Mcintosh 2012. Radium isotope values from Rowan et al 2010.

which is closer to ratios reported for wastewaters from conventional oil and gas wells in the Appalachian Basin (0.79 to 1.61 range).[5] The increase in $^{228}Ra/^{226}Ra$ ratio could reflect a change in the relative proportions of the different types of wastes treated at the facility, with a decrease in the percentage of the Marcellus flowback.[11]

The $\delta^{18}O$ and δ^2H values of wastewater effluent ($\delta^{18}O$ = −3.85‰ to −4.39‰; δ^2H = −40.8‰ to −45.6‰) overlapped with the values reported for produced water from western PA wells[2,4] and were higher than background surface water in western PA ($\delta^{18}O$ = −6.4‰ to −9.4‰; δ^2H = −41.7‰ to −60.8‰) (SI Figure S2). The wastewater effluent also had a different δ^2H - $\delta^{18}O$ slope relative to the local meteoric water line (LMWL).[20] The $^{87}Sr/^{86}Sr$ ratios of the wastewater effluents ranged from 0.7101 to 0.7111 and are consistent with the isotopic ratios of the Marcellus brines (Figure 2).[9,18] These

Figure 2. Variations of $^{87}Sr/^{86}Sr$ isotopic ratios in flowback fluids and produced waters from the Marcellus Shale, acid mine drainage (AMD), treatment facility discharge, surface waters upstream of the treatment facility, river waters directly downstream of the facility, and background surface waters in western PA. The ranges in $^{87}Sr/^{86}Sr$ (0.7101 to 0.7108) of the discharge effluent and downstream river are consistent with reported values for Marcellus flowback waters[9,18] and distinct from AMD (0.7145), background river values upstream of the facility (0.7131), and the range of background samples of surface water in western PA (0.7122−0.7145).

values are distinct from the $^{87}Sr/^{86}Sr$ ratios of acid mine drainage (AMD; 0.7145−0.7146), surface water collected upstream of the facility (0.7130 − 0.7131), and background surface water (upstream from any discharge site) samples collected in western PA (0.7122−0.7145; Figure 2). We observed a slight increase in $^{87}Sr/^{86}Sr$ in the effluent with time, which is consistent with the changes we observed in the $^{228}Ra/^{226}Ra$ ratios. One possible explanation for this change is a decrease in the relative volume of Marcellus wastewater treated at the investigated brine treatment facility during 2012. Overall, the use of multiple geochemical and isotopic tracers (Br/Cl, $^{87}Sr/^{86}Sr$, $^{228}Ra/^{226}Ra$, $\delta^{18}O$, and δ^2H) confirms that a large fraction of the discharged effluent from the investigated site originated from wastewater associated with shale gas development, at least during 2010−2011.

Salt Flux. We calculated the total flux of salts discharged by the facility to the stream by multiplying the mean

concentrations of dissolved salts in the effluent by the total discharged volume of effluent. We assume the average concentration of salts in the effluents reported in this study and the reported discharge flux (0.585 MLd) reflect the yearly effluent flux from the Josephine brine treatment facility (http://www.ahs.dep.state.pa.us/NRS/, Josephine facility; ID = PA0095273). Our calculations show that the total annual chloride and bromide fluxes to the stream were 17.4×10^3 and 136.5 t/year, respectively. For comparison, the annual chloride flux of the upstream river was only 4.8×10^3 metric tons/year. Therefore averaged over the year, the discharged effluent from the treatment facility contributes about 78% of the total downstream chloride flux from only 0.1% of the average flow volume (SI Table S4).

Maloney and Yoxhiemer (2012)[7] reported a total of 390 ML of Marcellus wastewater disposed to wastewater treatment plants during 2011. Lutz et al. (2013)[8] reported larger volumes disposed at treatment facilities, 1752.8 ML in 2010 and ~1200 ML in 2011. Wilson and VanBriesen (2012)[6] estimated Marcellus wastewater disposal to treatment plants increased both TDS and Br loading to downstream drinking water sources. Assuming that the studied site represents the Marcellus waste stream approximately, we estimate that in 2010–2011 the overall chloride flux (flux = discharge volume x concentration) to streams directly from Marcellus wastewater disposal was between 32×10^3 and 143×10^3 metric tons/year. Similarly, bromide fluxes were between 250 and 1,130 t/year. For comparison, these estimates would theoretically represent between 4.5% and 17% of the total annual chloride flux (684×10^3 metric tons/year) in an Ohio River with "background" chloride concentration of 24 mg/L and an average flow rate of 28.5×10^6 ML/year measured near Pittsburgh (SI Table S5). The relative contribution of bromide to the Ohio River from Marcellus wastewater disposal was larger, between 19.5% and 89%. The Ohio River was selected as an example because the vast majority of disposal facilities are located within its watershed (Figure 1).

Effects on Surface Water Quality. Surface water samples collected downstream of the wastewater effluent discharge in Blacklick Creek showed a significant dilution relative to the effluent for concentrations of all major elements (Table 1 and SI Tables S1 and S6). To evaluate the impact of the wastewater discharge, we calculated the enrichment factors (EFs) for each element, using the concentrations measured at downstream sites divided by the upstream concentrations. For a conservative element like chloride, the EF was >6000 at the point of discharge. The EF substantially decreased downstream as the effluent mixed with the streamwater. However, an EF value of 16 for chloride was recorded 1.78 km downstream of the effluent discharge (Figure 3a). Likewise, bromide concentrations were very low in upstream samples (0.03–0.1 mg/L) and were enriched by 6000–12 000 in the wastewater effluent. The downstream bromide EF values at distances of 300, 600, and 1780 m were 186, 33, and 37, respectively (Figure 3b). Our data show that in spite of a major dilution of the bromide-rich wastewater effluent, downstream river water had a significant bromide enrichment of almost 40 fold even at a distance of 1.78 km from the discharge site (although this conclusion is based on a single sampling event during low ~5 m^3/s streamflow). Overall, downstream concentrations were significantly higher than upstream concentrations ($p < 0.01$, Wilcoxon-Mann–Whitney test; SI Table S6).

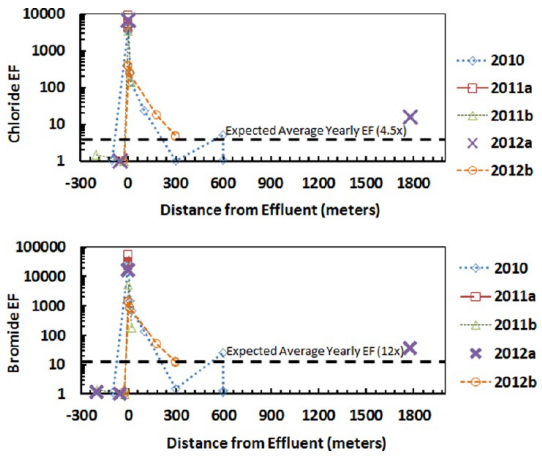


Figure 3. a and b. Surface water enrichment factors (EFs) in logarithmic scale of Cl and Br plotted versus distance from the discharge site of the investigated treatment facility in western PA. EFs were calculated relative to upstream surface water concentrations for each of five sampling events. Samples plotted upstream (values on the *X*-axis between −300 and −25) include both surface water samples collected directly upstream of the discharge site as well as acid mine drainage (AMD) contribution to the stream near the facility. The data show variability in concentrations during the same sampling event at the same distance downstream due to differential mixing of the effluents and river waters perpendicular to streamflow. Values of the calculated average yearly EFs within the stream are marked in dashed lines.

The EF data calculated above represent single sampling events. A more robust estimate of yearly average EF in the stream can be determined by using the average concentrations of bromide upstream of the facility (0.045 mg/L) and in the effluent (643 mg/L), combined with the average streamflow (756 MLd) and the treatment facility's reported discharge rate (0.585 MLd for 2012). Our calculations reveal an average yearly EF of 4.8 and 12.3 for Cl and Br, respectively (Figure 3a and b). It is important to note that this is an average EF of the total salt flux, and seasonal fluctuations in streamflow can substantially alter the EF on any given day. However, the overall bromide enrichment in river water could be critical to downstream municipal water treatment plants, given the potential formation of carcinogenic trihalomethane compounds in chlorinated drinking water upon chlorination of water with even slightly enriched bromide.[6,19]

More reactive constituents such as Mg, Ca, Ba, Sr, and Na (SI Figures S3a–e) showed lower EFs in the wastewater effluent discharge (200 to 20 000), which likely reflects the partial removal of these metals during the treatment process. Much lower EFs (1–3) were also recorded in the downstream surface water sites, inferring an additional uptake of these elements in the river sediments and potentially limited impact on the streamwater quality. The $^{87}Sr/^{86}Sr$ measured in downstream river waters (0.7102–0.7130; Figure 2) were in many cases identical to the wastewater effluents and significantly lower relative to the upstream values (0.71307–0.71309). The investigated stream was also influenced by AMD discharge with $^{87}Sr/^{86}Sr$ of 0.71455–0.71447, higher than values measured upstream (~0.713) and other reported values of AMD in western Pennsylvania (~0.712[21] and 0.712–0.718[22]). Overall, our data show that in spite of the dilution of the wastewater effluent in the river system, different elements, in

dx.doi.org/10.1021/es402165b | Environ. Sci. Technol. XXXX, XXX, XXX–XXX

particular chloride and bromide, were elevated in downstream water compared to the upstream river.

Effects on Radium in Stream Sediments. The ^{226}Ra activities in both the background river sediments and the sediments in Blacklick Creek directly upstream of the discharge were low (22.2 Bq/kg to 44.4 Bq/kg; Figure 4; SI Table S3)

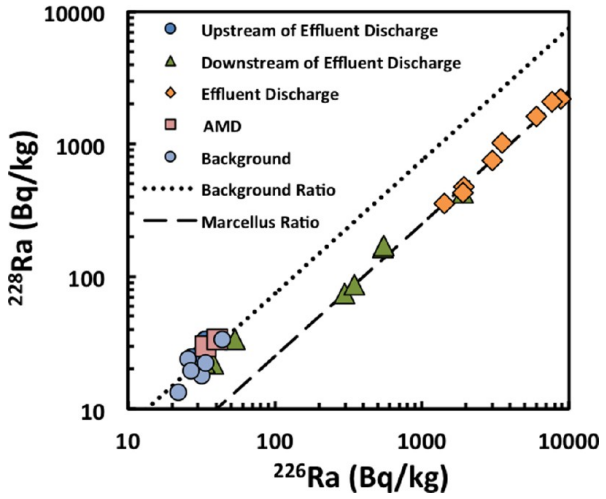


Figure 4. Activities of ^{228}Ra versus ^{226}Ra (Bq/kg) in river sediments collected upstream, adjacent, and downstream of the wastewater discharge site. Note that the maximum of both ^{226}Ra (8732 Bq/kg) and ^{228}Ra (2072 Bq/kg) activities were from samples collected in river sediments adjacent (<10 m) to the effluent discharge point and are 200 times greater than any sediment sample collected upstream of the facility or any background sediment samples collected from other western PA surface waters. The ^{228}Ra/^{226}Ra ratio (0.22 - 0.27) in the sediments at the discharge point is consistent with Marcellus brine and flowback waters (dashed line; ratio = 0.25). This isotopic signature measured in sediments from the discharge site is distinct from any background river sediment samples and acid mine drainage (AMD) with higher ^{228}Ra/^{226}Ra ratios (0.56–0.97; dotted line ratio of 1).

with ^{228}Ra/^{226}Ra ratios of 0.56–0.97. These Ra activities are consistent with background Ra activities reported in soils of western New York (mean ^{226}Ra = 33.3 Bq/kg and ^{228}Ra =51.8 Bq/kg[23]) and background river sediments (4–126 Bq/kg[24] and 44 Bq/kg to 91 Bq/kg for suspended matter[25]). In contrast, immediately adjacent to the treatment facility discharge site we recorded much higher maximum activities of both ^{226}Ra (8732 Bq/kg) and ^{228}Ra (2072 Bq/kg) in the sediments (SI Table S3; Figure 4). These Ra activities were 200 times greater than any background sediment samples collected either upstream of the facility or from other western PA rivers (SI Table S3) for sediment samples of similar grain size (SI Table S7). The mean values of all sediment samples collected from within 10 m of the discharge site (n = 7) were 4255 Bq/kg and 1110 Bq/kg for ^{226}Ra and ^{228}Ra, respectively. These radioactivity levels are typical values for technologically enhanced naturally occurring radioactive material (TENORM), and are above management regulations in the U.S. that range from 185 to 1850 Bq/kg (5 to 50 pCi/gram; http://www.tenorm.com/regs2.htm). For example, in Michigan a radiation threshold that would require transportation of solid waste to a licensed radioactive waste disposal facility is 1850 Bq/kg or 50 pCi/g.[26] Consequently, our data show that in spite of a significant reduction in Ra activities in the discharge water, the treated effluent has a significant impact on the sediments in Blacklick Creek because Ra has apparently adsorbed and accumulated on the sediments locally at the discharge site (SI Tables S3 and S6).

The ^{228}Ra/^{226}Ra ratio measured in the river sediments at the discharge site (0.22–0.27) is consistent with ratios reported for Marcellus flowback and produced water[5] and lower than the ratios recorded in all other background sediment samples we collected throughout western PA (0.56–0.97; SI Table S3; Figure 4). The relatively low ^{228}Ra/^{226}Ra ratio in the sediments near the discharge site likely represents the influence of recent discharge of Marcellus flowback and produced waters. Because the decay of ^{228}Ra (5.76 years half-life) is faster than ^{226}Ra (1600 year half-life), discharge of fluids with ^{228}Ra/^{226}Ra of ~0.9 would also result in ^{228}Ra/^{226}Ra ratios measured in the sediments of ~0.22–0.27 after 10 to 12 years of decay. Given the longer history (i.e., several decades) of conventional oil and gas wastewater disposal to streams in western PA, past disposal of conventional oil and gas waste would likely result in much lower ^{228}Ra/^{226}Ra ratios. The accumulation of Ra in the river sediments therefore appears to be primarily related to adsorption from recent wastewater discharge dominated by unconventional shale gas wastes.

A large portion (>50%) of the brine treated by the facility in 2010 and 2011 was Marcellus Formation flowback,[11] with an average reported activity of 185 Bq/L.[5] Assuming that the mean value of combined ^{226}Ra and ^{228}Ra reported for Marcellus flowback and produced waters by Rowan et al. (2011)[5] represented the brine accepted and treated at the facility, the ^{226}Ra + ^{228}Ra activities in the treated effluents indicate a 1000-fold reduction in radium (Table 2). The wastewater treatment through the facility involves Na_2SO_4 addition that likely promotes radium coprecipitation with solid barium sulfate within the facility. The accumulation of Ra as this solid sludge that is then hauled to residual landfills represents a TENORM, common in oil and gas industry wastes such as scale and sludge, that could pose significant exposure risks if not properly managed.[27,28]

Based on the measurements of drastically reduced radium in the effluent, we calculated the total radium likely removed from the wastewater by the treatment facility. Assuming one-half of the 0.585 MLd treated in the facility in 2010 was Marcellus flowback or produced water with an estimated Ra activity of 180 Bq/L, and that for every liter of liquid wastewater, 100 g (10%) of solid/sludge precipitated out of the liquid during the wastewater treatment process, the solid product would contain roughly 900 Bq/kg of radium. This estimated level of radiation in the waste treatment solids/sludge would then exceed the U.S. regulations for ^{226}Ra disposal to soil of 5–15 pCi/g (185–555 Bq/kg) (http://www.tenorm.com/regs2.htm). These values could also exceed many of the typical municipal landfill limits for TENORM in the U.S., which range from 5 to 50 pCi/gram (185–1850 Bq/kg; http://www.tenorm.com/regs2.htm). It should be noted that our calculations for the possible Ra content in the treatment residual solids assume that only wastewaters from shale gas wells contained Ra. Yet, produced waters from conventional oil and gas wells in Pennsylvania and New York also have elevated levels of radioactivity, similar to those from the Marcellus Formation.[5]

Although the treatment facility substantially reduces the Ba and Ra in the treated discharge, there is also still a flux of Ra to the stream that we estimate to be 39×10^6 Bq/year (i.e., 0.585 MLd × 0.185 Bq/L × 365 days). However, our data show that the Ra likely does not remain in the liquid phase and flow

dx.doi.org/10.1021/es402165b | Environ. Sci. Technol. XXXX, XXX, XXX–XXX

downstream; instead, most of the Ra appears to be adsorbed and retained in river sediments near the discharge site. Because Ra adsorption increases with decreasing salinity (i.e., the dilution of dissolved salts),[29−31] the mixing of the saline wastewater effluents and upstream low-saline water apparently enhances Ra adsorption onto the sediments.

The sediments we analyzed near the treatment facility could be remobilized and transported downstream during storm events, but the major impact of Ra appears to be localized (<200 m downstream; Table 1; SI Table S1), creating a zone of concentrated Ra in the river bottom sediments. The accumulation of Ra in sediments locally could pose significant ecological risks to benthic organisms in particular. Bioaccumulation of Ra is known to occur in freshwater fish, invertebrates, mollusks, and shells with reported concentration factors (CF) of 100−1000.[24,32−34] Although the most likely bioaccumulation pathway is through the benthic environment, radium also accumulates in freshwater plants with an apparent CF of 432 in algae[35] and up to 1000 in phytoplankton in rivers[24] although the majority of these studies examined dissolved radium values. Further investigations should focus on the possible bioaccumulation of radium in areas of wastewater discharge, spills, or other areas where shale gas wastewater is released to the environment.

In summary, the discharge of wastewater effluent to surface water has a discernible impact on the water quality of the stream. The chloride concentrations 1.7 km downstream of the treatment facility were 2−10 times higher than any chloride concentrations recorded in any background western PA streams that we examined. The average yearly EF of chloride in the stream was calculated to be 4.6 times background concentrations. These data support recent studies that suggest treatment facilities have an impact on concentrations of chloride throughout western PA.[6,12,13] These results also demonstrate that even a 500−3000 dilution of the wastewater effluent is not sufficient to reduce bromide content to background levels; thus, discharge of wastewater could potentially increases the concentrations of Br in downstream drinking-water treatment facilities.[6]

Our data show that the geochemical signature of Marcellus wastewater is apparent, even after treatment, in the effluents from the treatment facility and in the downstream water and sediments. The majority of elemental chemistry and isotopic ratios ($\delta^{18}O$, $\delta\ ^{2}H$, $^{87}Sr/^{86}Sr$, $^{228}Ra/\ ^{226}Ra$) in treated wastewater effluents during 2010 and 2011 were similar to the compositions of flowback and produced waters from the Marcellus shale gas operations. Therefore we conclude that despite treatment, the isotopic ratios in the effluent can still be used as tracers for delineating the sources of oil and gas wastewaters.

Overall we show that treatment in Josephine Brine Treatment Facility reduces the concentrations of some elements before releasing them into the stream, but wastewater discharge nevertheless reduces the quality of downstream surface water and sediments. Discharge of conventional and unconventional shale gas wastewaters has generated a flux of contaminants to surface water that created an extended mixing zone with high concentrations above background levels. These fluxes include elevated bromide concentrations in downstream river water and the generation of TENORM contamination in stream sediments at the discharge site. Given the long decay rate of ^{226}Ra (i.e., half-life of 1600 years), Ra and its decay-product nuclides will remain in the environment generating radiation over a long time period. Future studies should explore Ra bioaccumulation and other ecological effects at wastewater discharge sites. Moreover, advanced treatment technologies should be applied to prevent discharge of contaminants, including Ra and Br, to the environment in areas of shale gas development and hydraulic fracturing. Future studies should also examine the disposal options for residue solids generated during the treatment process and their suitability for disposal in municipal landfills (Subtitle C and D), which may not be designed for the expected high levels of radioactivity and could pose potential groundwater contamination problems in the future.

■ ASSOCIATED CONTENT

Supporting Information

A Supporting Information (SI) section contains additional text describing methods in greater detail and background information on waste disposal methods. Additional tables and figures of chemical and isotopic are also included. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

We gratefully acknowledge funding from Fred and Alice Stanback and Park Foundation to the Nicholas School of the Environment. We thank William Chameides, the Dean of the Nicholas School of Environment for supporting this research. Gary Dwyer provided guidance on sample preparation and analysis. Kyle Ferrar and Drew Michanowicz of the Center for Healthy Environments and Communities and Samantha Malone of Fractracker.org facilitated field-sampling activities for multiple sampling events. Jon Karr and the Duke Environmental Isotope Laboratory (DEVIL) performed analyses of $\delta^{18}O$, and $\delta^{2}H$ of surface water samples. We thank the editor, and three anonymous reviewers for improving the quality of this manuscript.

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RE: Natural Gas Brine Dispersal on Roadways and the Risk of Surface and Groundwater Contamination (Comments on DEP Permit # WMGR064)

Dear Mr. Walters,

Introduction

On behalf of Damascus Citizens for Sustainability (PO Box 147, Milanville, PA 18443), I have reviewed the Special Conditions General Permit WMGR064 amendment that proposes the authorization of the use of natural gas well brine for roadway pre-wetting, anti-icing, and roadway de-icing. Our comments relate to the potential degradation of freshwater resources stemming from overland transport of gas well brines and contaminants within it to waterways, lakes and reservoirs. In addition, we address the certain likelihood of brine and contaminant infiltration to groundwater resources incident to aquifers, freshwater wells, and surface water.

I offer comments based on my training as a geologist, hydrogeologist, and hydrologist with 30 years of professional environmental experience which includes work conducted for the New York State Attorney General's Office (Environmental Protection Bureau), Oak Ridge National Laboratory (Environmental Sciences Division), the New York City Department of Environmental Protection, and as an independent environmental consultant as President of HydroQuest. I have conducted detailed assessments of streams, wetlands, watersheds, and aquifers for professional characterizations, for clients, and as part of my own personal research. I have authored numerous reports and affidavits related to this work and have made presentations to judges and juries. In addition, I have published papers and led all day field trips relating to this work at professional conferences. I have also authored extensive comments relating to exploratory wells in the Delaware River Basin, as well other material related to gas drilling and hydraulic fracturing.

This general permit will fail to protect the public and the environment. General Permit WMGR064 paragraph 12 acknowledges the "… *potential for groundwater contamination* …" This permit does not adequately address the short and long-term hydrologic picture and, as such, willingly seeks to conduct "… *an activity that harms or presents a threat of harm to the health, safety, or welfare of the people or the environment*." (Paragraph 14). Similarly, paragraph 6 states that: "*The activities authorized by this permit shall not harm or present a threat of harm to the health, safety, or welfare of the people or environment of this Commonwealth.*" The serious contaminant risk associated with the proposed "beneficial" use of natural gas well brines is accented in paragraph 21 of the Special Conditions:

> *"The permittee/registrant shall immediately notify the Department's Emergency Hotline at (717) 787-4343 and the appropriate DEP regional office in the event of any spill of natural gas well brines in a quantity* ***capable of reaching surface water*** (emphasis added) *and shall take immediate action to protect the health and safety of the public and the environment."*

As a hydrogeologist with 30 years of professional experience I am well aware that road salt which has a high sodium chloride content, like brines, has a long history of contaminating groundwater supplies – often with related litigation. For example, as a hydrogeologist with the New York State Attorney General's Office (Environmental Protection Bureau), I worked with the NYSDEC and NYS Thruway Authority to document the migration of road salt from the road edge to a number adversely impacted homeowner wells. Here, the NYS Thruway Authority ultimately paid to extend a water line to provide potable water to homeowners. This situation spurred extensive research which documented the magnitude of road salt based groundwater contamination cases throughout the United States. This work, in turn, led to drafting legislation oriented toward protecting aquifers from road salt contamination. The proposed application of brines under General Permit WMGR064 would present a similar hydrogeologic risk to groundwater and surface water resources – with the added risk of widespread dispersal of additional and, quite likely, unknown fracking-related chemical compounds. The dispersal of gas well brines on our roadways, potentially laced with toxic and carcinogenic chemical compounds, is completely unnecessary and will needlessly jeopardize our finite freshwater resources. General Permit WMGR064, and any other related permits (e.g., for dust suppression) should be abandoned in deference to traditional means of de-icing our roadways. This permit should be denied.

In part, these comments relate to the potential degradation of freshwater resources stemming from overland transport of gas well brines and contaminants within it to waterways, lakes and reservoirs. In addition, we address the certain likelihood of brine and contaminant infiltration to groundwater resources incident to aquifers, freshwater wells, and surface water.

Production-Related Brines

It is likely that gas well brine wastewater produced along with gas or oil production will be

targeted for de-icing, dust suppression, and related uses. In this case, it is likely that an even greater percentage or concentration of fracking-related chemicals will be present vs. further along in the final production life of wells. Concentrated and chemically-laden brines should not be discharged into the environment. This is not a beneficial use. These brines need to be properly treated and disposed of.

Gas Well Closure

Former natural gas wells should be immediately plugged and abandoned following cessation of production. They should not be adapted for yet another use (i.e., brine extraction) that will, without doubt, degrade the water quality in the Commonwealth. General Permit WMGR064 seeks to provide a beneficial use of natural gas well brines for roadway and walkway purposes. Although unclear in the permit description, one underlying premise here may be that gas wells should remain open for a period of time after productivity diminishes. This would require that wells not be fully plugged and abandoned following cessation of gas production. To delay permanent closure of any natural gas well actively accepts and knowingly extends the great environmental and water quality risks attendant to gas production in the Commonwealth and elsewhere. On behalf of Damascus Citizens for Sustainability, the Delaware Riverkeeper Network, and independently on behalf of HydroQuest, HydroQuest has documented the environmental risks to freshwater aquifers stemming from gas wells.

All gas wells should be immediately plugged and abandoned once production is stopped because the durability and mechanical properties of well sealant materials are NOT sufficiently advanced such that freshwater aquifers will be safely protected for hundreds of thousands of years. Existing and so-called "state-of-the-art" plugging and abandonment (P&A) practices and materials are not sufficiently advanced to insure long-term isolation between saline and freshwater zones. The aquifers we enjoy today took about a million years to form and can reasonably be expected to last another one million years (see, for example, attached *Aquifer Protection Expert Fact Sheet*). [This Fact Sheet may also be viewed and downloaded at: http://hydroquest.com/Hydrofracking/] Without unnatural alteration from gas drilling activities, aquifers should be capable of providing potable water for future generations for another one million plus years. Industry documentation establishes that, under the best of circumstances, cement and steel used to effect zonal isolation may last up to 100 years and 80 years, respectively – often far less. Once the inevitable failure of cement sheath and casing sealant material occurs, additional contaminant migration pathways are available. Then, methane released under pressure from failed cement sheaths and casings follows fractures to homeowner wells, water bodies, and the land surface. With continued degradation of cement sheaths, concentrated brine fluid will rise under hydraulic pressure and commingle with freshwater aquifers. Thus, under this scenario, the intended "beneficial use" of natural gas well brines requires that freshwater resources remain at risk for extended periods of time.

As stated in Chapter 7 of Pennsylvania's Well Abandonment Procedures (Section 7.1 Introduction):

> *"Unsealed or improperly sealed wells **may threaten public health and safety, and the quality of the groundwater resources*** (emphasis added***)***. *Therefore, the proper abandonment (decommissioning) of a well is a critical final step in its service life. ... Proper well abandonment accomplishes the following: 1) eliminates the physical hazard of the well (the hole in the ground), 2) eliminates a pathway for migration of contamination, and 3) prevents hydrologic changes in the aquifer system, such as the changes in hydraulic head and the mixing of water between aquifers."*

Clearly, any action regarding non-producing gas wells, other than immediate plugging and abandonment, should be banned and construed as not following the intent of existing well field regulations. Extended gas well life threatens freshwater resources in the Commonwealth, with the result being the dispersal of contaminants that hydrologically must and will enter surface and groundwater resources if spread in this manner – anything but a "beneficial use". This permit must be denied.

Gas Well Brines

De-icing chemicals commonly enter nearby groundwater flow systems and degrade water quality. State and Federal drinking water standards for groundwater, against which adversely impacted homeowner well waters will be compared for gas well brine chemicals, are limited and do **NOT** adequately require sampling and analysis for all of the many toxic and carcinogenic chemical compounds used in fracking/drilling fluids. As a result, State sign-off on supposedly clean, potable, groundwater will occur while people's health may remain in serious jeopardy from unknown and untested brine chemicals. Therefore, this permit must be denied.

Natural gas well brines are comprised of concentrated solutions of sodium chloride, laced with numerous known and unknown hydrofracking chemicals, many of which may be toxic. The Pennsylvania Department of Environmental Protection developed a Fact Sheet that pointedly explains to the public the definition and the potential "beneficial use" of brine in the Commonwealth:

> *"Brine is the general term used for wastewater produced along with oil or gas; it can be very salty, therefore, **injurious to plants and aquatic life*** (emphasis added)."

It is not prudent from a hydrologic and water quality standpoint to intentionally disperse **wastewater** throughout the Commonwealth so that it will flow and infiltrate into our surface water and groundwater resources. Whether brine contaminants are applied on dry days, wet days, 50 or 200 feet from streams or houses, or in one concentration or another is largely irrelevant. The hydrology is simple and straight forward. Under wet hydrologic conditions, and with repeated applications, whether today, tomorrow, or in two months – the contaminants **will move** into our waterways, reservoirs, and aquifers (i.e., toward our drinking water supplies). Once significant precipitation occurs, brines will then be mobilized and transported away from source areas. To categorize gas well brine applications under the term "beneficial use" can only be considered from a financial perspective relative to saving gas companies from having to pay

to properly dispose or treat their wastewater. The concept of intentionally dispersing gas well wastewater into our environment defies all common sense. Thus, this permit application should be denied.

General Permit WMGR064, Table 1, provides acceptance criteria (i.e., allowable concentrations) for fourteen chemical parameters, some of which are not typically contaminants when present in normal background concentrations in groundwater. The comparative table provided below readily indicates that this general permit will knowingly allow chemical laden brines to enter contaminant-free surface and groundwater flow systems.

Parameter	**Allowable Level Pre-wetting (mg/l except pH)**	**Primary or Secondary Drinking Water Standard (mg/l except pH)**	**Minimum number of times in excess of Groundwater Standard**
TDS	>170,000	500	>340
Chloride	>80,000	250	>320
Sodium	>40,000	-----	------
Calcium	>20,000	-----	------
pH	5 to 9.5	6.5-8.5	10-50
Iron	<500	0.3	<1,667
Barium	100	2	50
Lead	10	0.005	2,000
Sulfate	<1,000	250	<4
Oil & Grease	< 15	-----	------
Benzene	<0.5	0.005	<1,000
Ethylbenzene	<0.7	0.7	<1
Toluene	<1	1	<1
Xylene	<1	10 (total)	------

Even if we erroneously assume that the only chemicals present in brine-rich waters pumped from gas wells are all included in the above parameter list, many of those present will assuredly contaminate surface and groundwater resources adjacent to and beyond roadways. Chloride, for example, is extremely soluble in water and is readily transported in both surface and groundwater flow systems. It is well-recognized as a contaminant that has degraded numerous homeowner wells. Studies have shown that it often moves coincident with large snowmelt, precipitation, and runoff events. Repeated applications provide regular replenishment of contaminant source material. The addition of fracking-related chemicals to traditional de-icing materials will serve to greatly increase the health risk to the general populous and the environment. To limit permit *acceptance criteria* largely to chemical parameters that have established MCL's would ignore hundreds of other chemicals that are used in underground fracking injection, plus many others that are hidden from public scrutiny by being labeled as "proprietary". This would oppose the best interests of the population at large. A comprehensive listing of hydrofracking related chemicals is provided in the text and many tables of Chapter 5 of

the NYS Revised DSGEIS. The material in this chapter (http://www.dec.ny.gov/docs/materials_minerals_pdf/rdsgeisch50911.pdf) is hereby incorporated by reference. Permit acceptance criteria must be greatly expanded to include all toxic and carcinogenic chemicals that may well be within the brine "chemical soup" as indicated within Chapter 5 of the NYS DSGEIS. Allowable levels of these many chemical parameters must be based on detailed toxologic testing and risk assessment evaluations. In addition, individual testing of gas well brines should be conducted at least annually on a well-specific basis.

Many more contaminants that are present in flow back water are also likely to be present in brines pumped from gas production wells. Some of these are extremely toxic, some are carcinogens, and others have not been adequately studied to determine their potential impact on humans and animals (e.g., 2-butoxyethanol, formaldehyde). For example, Dr. Ronald Bishop details many of the toxic qualities and potential health impacts associated with chemicals wastes found in gas well flow back water (http://www.fmce.org/Beyond%20MSDS.pdf; *Beyond MSDS: A Review of Hazardous Materials Used by New York's Natural Gas Industry*). Dr. Bishop's report is hereby incorporated into this comment letter by reference. As discussed above, these and all other hydraulic fracturing and drilling fluid chemicals should be comprehensively assessed by toxicologists and should then be added to the very short and incomplete list above. There are hundreds of chemicals used in the hydraulic fracturing and well drilling process, many not disclosed to the public. To not identify and test for **all** these chemicals and to then exclude them from the "*acceptance criteria*" is short-sighted and irresponsible, especially in light of the many documented and serious public health risks.

Hydrology Discussion

Under 25 Pa. Code § 287.611(a)(3), the Department of Environmental Protection—here through the Bureau of Waste Management—can issue a general permit for beneficial use of residual waste if it can be used "without harming or presenting a threat of harm to the health, safety or welfare of the people or environment" of the Commonwealth. **Hydrologically, this cannot be done.** Slow groundwater flow rates and rapid surface runoff will recharge aquifers and streams with brines and related contaminants. Thus, contaminant plumes will move toward homeowner wells and streams. These plumes, like those present at other contaminant sites, need to be treated as outwardly expanding contaminant plumes that warrant expensive, full-scale, hydrogeologic characterization, groundwater clean-up, and remedial action. Hydrogeologically, overland brine dispersal is short-sighted and virtually guarantees degradation of both surface and groundwater resources. The draft permit regulations need to be modified to reflect characterization and clean-up of brine-rich waters and all related toxic chemicals present and moving within the environment.

Brine application is not needed for dust suppression. Dust suppression can be achieved with the application of clean water and need NOT contain ANY brines or chemical additions that pose an unnecessary threat to clean surface and groundwaters of the Commonwealth. As such, General Permit WGMR064 should be abandoned.

Tracers

Tracer additions to brines would provide a much needed checks and balance type approach to scientifically and legally address claims of brine excursions. On the one hand, tracers would readily allow brine applicators to show they are not behind brine-related contaminant issues that are not of their making, while on the other hand it would remove the oneness of proof from homeowners actually adversely impacted. **Importantly, there is no reason whatsoever that ALL brine applications should not require tracer additions and monitoring effective immediately, even before general Permit WMGR064 is approved. This would demonstrate a good faith effort on behalf of the regulators.**

To reduce the onus of legal and expert consultant costs to homeowners, **all** brine waters/fluids should first have company-specific tracers added to them so contaminant source and responsibility can be properly assigned (should this permit be approved). The addition of gas well company-specific tracers is needed to provide sufficient documentation of uncontrolled non-point source de-icing chemical excursions from roadways and walkways. Otherwise, the limited number of Maximum Contaminant Level (MCL) chemicals may erroneously instill a false sense of potable water quality when people's health may be severely impacted. The enforcement of these provisions is nearly impossible. The department cannot consider approval of this permit application without a highly detailed enforcement plan to be implemented with the completed permit application. An enforcement plan should be part of the permit. Without this, the permit should be rejected.

Proposed Modifications in the Event the Permit Application is Approved

Substantively, the proposed modifications present a risk of damage to human health and the environment and should therefore be rejected. Hydrologically, dispersed/applied brines will enter and degrade the environment in a very non-beneficial manner. Application rates, timing, and set-back distances will do little other than postpone the inevitable. Besides, there is no provision for enforcement in this permit application. Therefore, we recommend rejection of this permit. If, however, the Bureau decides to go ahead with the new uses, it should include the following criteria in the General Permit in order to substantively comply with its mandate to somewhat protect human health and the environment:

- THIS IS THE MOST IMPORTANT NEW CRITERIA. Add company-specific chemical tracers to all gas well fluids prior to brine application so that contaminant responsibility, aquifer restoration and alternate water supply costs may be properly designated. Tracer experts should be used to determine appropriate tracers and concentrations so as to fully allow for detection in degraded surface and groundwater resources of the Commonwealth.

- **NO PERMIT APPROVAL SHOULD BE POSSIBLE WITHOUT THIS CRITICALLY IMPORTANT CRITERIA DESIGNED TO PROTECT BOTH ADVERSELY IMPACTED HOMEOWNERS AND BRINE APPLICATORS. UNWILLINGNESS TO USE TRACERS TO DOCUMENT CONTAMINANT RESPONSIBILITY SHOULD BE CAUSE ALONE TO NOT APPROVE GENERAL PERMIT WMGR064**;

- Develop appropriate acceptance criteria for the new uses that includes all chemicals used in gas well drilling and fracking;

- Conduct comprehensive chemical and toxicological testing of fluids from all gas wells targeted for brine extraction for ALL chemicals previously used in them during construction and development. Sample collection and analysis should be conducted by an independent party;

- Conduct baseline chemical testing of all well water and surface waterways, lakes, and reservoirs for ALL chemicals previously used in the gas wells to a distance of 2,000 feet outward from all roadways and walkways;

- Provide for regular testing of brines including gas well chemicals used every six months or sooner where degraded groundwater and/or surface water is suspected;

- Provide for regular testing of soil and groundwater within 2,000 feet of application for ALL chemicals used in gas well fluids during construction and operation of gas wells;

- Provide criteria to stop all brine spreading should **any** surface or groundwater contamination be documented;

- Establish a 2,000 foot limit on brine application distance from water bodies and streams;

- Special Protection Waters, Caves & Mines. Recognize, locate, investigate, inventory, and characterize rare, threatened, and endangered species and their habitats which are likely to be degraded from brine-related contaminant excursions. Omit these habitat areas from brine applications, inclusive of a large buffer distance. Some of the species of greatest concern are endangered stream dwellers (i.e., Dwarf Wedge mussel [*Alasmidonta heterodon])* and assorted bat species (e.g., including the federally endangered Indiana bat [*Myotis sodalis]*). There are real environmental, water quality, health, and endangered species concerns regarding brine excursions into carbonate beds, inclusive of in caves and mines. Carbonate formations in portions of the Commonwealth are recognized among karst hydrologists as being karstic or cave/ conduit bearing in nature. Brine and related contaminants that may enter karstic

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solution conduits, from below or above, would quickly degrade groundwater and surface water quality;

- Add a monitoring section. The General Permit lacks detail on surface and groundwater monitoring. This should be added. Until such time as it can be demonstrated that adequate staffing is present to monitor this general permit, it should not be approved;

- Add an enforcement section. The General Permit lacks provision for enforcement. This should be added. Until such time as it can be demonstrated that adequate staffing is present to regulate and enforce this general permit, it should not be approved;

- Add record keeping detail by PA DEP. Detailed records of the quantity of brine fluids withdrawn and applied should be required;

- Add record keeping detail BY PA DEP. Detailed records of the exact location of brine applications should be required;

- Establish a very substantial escrow or bond type account for all brine applicators to off-set contaminant testing, aquifer restoration, and replacement water supplies costs for adversely impacted parties. This might be set-up on a fee per application basis;

- Establish a rigorous fee structure based on volume of brine application for applicators such that monies are regularly added to the coffers of the Commonwealth. Otherwise, there is no logical reason or beneficial use that may reasonably be attributed to intentionally applying brine wastewater that will threaten and degrade fresh surface and groundwaters of the Commonwealth; and

- Strengthen permit regulations to insure that brine applicators, and/or their suppliers, assume full legal and financial responsibility for contaminating aquifers and fully clean them up to the maximum extent possible **AND** develop permanent alternate water supply systems for all adversely affected water supplies. Permit regulations should be modified to provide for system operation and maintenance costs in perpetuity. As written, permit regulations do not have adequate provision to protect the health and safety of homeowners. The importance of this must be underscored because aquifer restoration from brine and gas field contaminants, even if cost were not an issue, may not be possible. Whereas monetary compensation to adversely affected homeowners may be warranted as settlement for inconvenience, property devaluation, and health issues, any settlements should in no way remove the

responsibility of brine applicators to restore the waters of the Commonwealth. Provision of whole house water filtration systems should not be an acceptable means of abdicating responsibility and liability.

Conclusions

The Bureau should reject the permit modifications, ban any and all gas well brine applications, and not allow the additional proposed uses because of the increased risk of contamination of groundwater, surface waters, and soil. The Bureau's proposed modifications, which will likely drastically increase the amount of brine being spread on Pennsylvania roads, present a threat of harm to the health, safety, and welfare of the people and the environment, and therefore the modifications should be denied.

The key to maintaining high quality groundwater and surface water throughout the Commonwealth is to NOT apply concentrated and contaminated brines at any time whatsoever. There is NO sound environmental benefit in applying brines anywhere, as they will eventually reach surface and groundwater resources. Thus, General Permit WGMR064 should be abandoned and gas well brine applications should be banned permanently. The Bureau should therefore deny the proposed modifications and ban gas well brine dispersal into the environment.

Sincerely.

Paul A. Rubin

Paul A. Rubin
Hyrogeologist
HydroQuest

CC: Damascus Citizens for Sustainability

Policy Analysis

Sources of Radium Accumulation in Stream Sediments near Disposal Sites in Pennsylvania: Implications for Disposal of Conventional Oil and Gas Wastewater

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Environ. Sci. Technol., **Just Accepted Manuscript** • DOI: 10.1021/acs.est.7b04952 • Publication Date (Web): 04 Jan 2018

Sources of Radium Accumulation in Stream Sediments near Disposal Sites in Pennsylvania: Implications for Disposal of Conventional Oil and Gas Wastewater

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KEY WORDS

Radium, Produced Water, Appalachian Basin, Marcellus Shale, Hydraulic Fracturing

ABSTRACT

In Pennsylvania, Appalachian oil and gas wastewaters (OGW) are permitted for release to surface waters after some treatment by centralized waste treatment (CWT) facilities. While this practice was largely discontinued in 2011 for unconventional Marcellus OGW, it continues for conventional OGW. This study aimed to evaluate the environmental implications of the policy allowing the disposal of conventional OGW. We collected stream sediments from three discharge sites receiving treated OGW between 2014-2017 and measured ^{228}Ra, ^{226}Ra, and their decay products, ^{228}Th and ^{210}Pb, respectively. We consistently found elevated activities of ^{228}Ra and ^{226}Ra in stream sediments in the vicinity of the outfall (total Ra = 90-25,000 Bq/kg) compared to upstream sediments (20-80 Bq/kg). In 2015 and 2017, ^{228}Th/^{228}Ra activity ratios in sediments from two disposal sites were relatively low (0.2-0.7), indicating that a portion of the Ra has accumulated in the sediments in recent (<3) years, when no unconventional Marcellus OGW was reportedly discharged. ^{228}Ra/^{226}Ra activity ratios were also higher than what would be expected solely from disposal of low ^{228}Ra/^{226}Ra Marcellus OGW. Based on these variations, we concluded that recent disposal of treated conventional OGW is the source of high Ra in stream sediments at CWT facility disposal sites. Consequently, policies pertaining to the disposal of only unconventional fluids are not adequate in preventing radioactive contamination in sediments at disposal sites, and the permission to release of treated Ra-rich conventional OGW through CWT facilities should be reconsidered.

INTRODUCTION

The large-scale development of unconventional shale gas in the Appalachian Basin has been associated with different types and mechanisms of water contamination, including the management and disposal of the oil and gas wastewater (OGW) that is comprised of flowback fluids and produced waters.[1-3] Flowback and produced waters from the Appalachian Basin are highly saline and enriched in naturally occurring radioactive materials (NORM).[4-7] Previous studies have demonstrated that NORM in formation waters mainly consists of radium-226 ($t_{1/2}$=1600 years) and radium-228 ($t_{1/2}$=5.8 years) from the uranium and thorium decay series.[7-9] Total Ra (^{228}Ra+^{226}Ra) activities have been measured in Appalachian Basin formation waters up to hundreds of Becquerels per liter (Bq/L; up to 660 Bq/L and 250 Bq/L for Marcellus and conventional produced waters, respectively)[7] that exceed by several orders of magnitude the activities typically measured in fresh surface waters (0.5- 20 mBq/L for ^{226}Ra) by several orders of magnitude.[10] Elevated ^{228}Ra and ^{226}Ra may pose environmental and human health risks if released to the environment, as they are carcinogenic,[11] bioaccumulate (concentration factors between sediment and aquatic plants and fish of 0.014 and 2.3-700, respectively),[12-17] persist in the environment due to their relatively long half lives, and decay into a suite of other radioactive elements including gaseous ^{222}Rn, ^{210}Pb, and ^{210}Po.

Due to their high salinity, unique chemistry, and immense volume, OGW pose significant management challenges when brought to the surface with hydrocarbons. In Pennsylvania, 43 million bbl of unconventional and 6.6 million bbl of conventional OGW were produced in 2014. A large fraction of this OGW (64% of unconventional OGW and 5% of conventional OGW; >50% of the combined total) was reused for hydraulic

fracturing operations.[18] A major option for disposal is injection underground via EPA Class II deep-well injection wells, but since there are a relatively limited number of these disposal wells in Pennsylvania, the OGW is often transported to neighboring states for disposal. Therefore, alternative disposal options in Pennsylvania consist of spreading on roads as a deicing agent or dust suppressant and treatment by wastewater treatment plants, including centralized waste treatment (CWT) facilities.[18] Treatment of OGW at these facilities has been described previously[19-21] and often includes the addition of Na_2SO_4 to promote the precipitation of metals, as well as Ra, before the treated OGW is discharged to local surface waters.

Due to concerns of contamination, in the spring of 2011 the Pennsylvania Department of Environmental Protection (PADEP) requested unconventional well operators to cease sending Marcellus OGW to wastewater treatment facilities. Although participation was voluntary, treatment of Marcellus waste at many wastewater treatment plants in Pennsylvania nearly ended by the fall of 2011.[22] However, these facilities continued to receive, treat, and dispose conventional OGW to the local streams.[18]

Several studies addressing this issue were published in 2013, relatively soon after Marcellus OGW treatment and discharge was discontinued. These studies showed that the releases of highly saline effluent causes direct contamination of the stream water at disposal sites, [19, 20, 23, 24] and also increases the risk of the formation of disinfection byproducts in downstream communities.[25] In addition to degrading water quality, Warner et al.[20] found that the release of treated OGW to Blacklick Creek, a tributary of the Allegheny River in Josephine, PA, resulted in the accumulation of Ra (^{226}Ra activities of 544- 8,759 Bq/kg) in stream sediments in close vicinity (<200 m) to the outfall. Skalak et

al.[26] found no increase in ^{226}Ra in stream sediments downstream of effluent sites from five wastewater treatment facilities. In two facilities, Skalak et al.[26] also collected sediments at the disposal sites, one of which was found to have ^{226}Ra activities slightly elevated (73 Bq/kg) above background (40 Bq/kg). These investigations, however, were conducted during the time period that Marcellus OGW were treated and discharged (2008-2011), or relatively soon after this practice was discontinued, and consequently the Ra accumulation in sediments has been attributed to contamination from the time period of high volumes of Marcellus OGW discharge.[20]

While much attention has been paid to understanding and mitigating contamination from unconventional OGW, the environmental impact from disposal of conventional OGW from CWT facilities has not been thoroughly investigated. Previous research has shown that conventional OGW from the Appalachian basin is also enriched in both ^{226}Ra and ^{228}Ra, with total Ra activities reaching 250 Bq/L (median 27 Bq/L).[7] Accordingly, we hypothesized that in spite of Marcellus OGW no longer being sent to wastewater treatment facilities, long-term release of conventional OGW by CWT facilities would still result in Ra accumulation in stream sediments at disposal sites.

In this study, we collected stream sediments from three disposal sites in PA receiving treated OGW. These include sediments from Blacklick Creek in Josephine, the Allegheny River in Franklin, and McKee Run in Creekside (Figure 1). Stream sediments were collected between 2014 and 2017 while the CWT facilities were not receiving Marcellus OGW but did report receipt of conventional OGW.[18] The objectives of this study were to (1) assess Ra accumulation and the ingrowth of Ra decay products in sediments of streams receiving treated conventional OGW; (2) use the U-Th series

disequilibrium to constrain the timing of Ra accumulation and determine whether the Ra in stream sediments reflects ongoing conventional OGW disposal or legacy disposal of Marcellus OGW; and (3) use the data to evaluate the environmental implications of current policies that solely regulate and restrict unconventional fluids and allow continued disposal of treated conventional OGW to the environment.

MATERIALS AND METHODS

Site Selection. We investigated three sites where OGW effluents were released to surface waters from CWT facilities (Figure 1). The CWT facilities that were chosen are defined by Standard Industrial Classification (SIC) codes that only relate to oil and gas wastes. Although the possibility that these facilities received other undocumented wastes during the study period is unknown, we are not aware of any other NORM-rich wastewater sources in the study area. These facilities include (1) the Pennsylvania Brine Treatment Josephine Facility ("Josephine Facility") in Josephine, PA which discharges treated OGW to Blacklick Creek; (2) the Pennsylvania Brine Treatment Franklin Facility ("Franklin Facility") in Franklin, PA, which discharges to the Allegheny River; and (3) Hart Resource Technologies Creekside Facility ("Hart Facility") in Creekside, PA, which discharges to McKee Run (Figure 1).

In 2010, the PADEP issued regulations that required effluents from wastewater treatment plants have total dissolved solid (TDS) levels below 500 mg/L. However, the Josephine, Franklin, and Creekside facilities were 3 of initially 27 facilities grandfathered in to previous regulations that do not strictly limit the TDS of effluents.[27] These three investigated facilities also reported that they stopped receiving unconventional OGW by

the end of 2011, following PADEP asking that well operators voluntarily stop sending unconventional OGW to wastewater treatment facilities grandfathered in to the less stringent TDS standards.[22, 27] Total conventional and unconventional waste sent to CWT facilities investigated in this study was compiled from the PADEP oil and gas reporting website for the years 2010-2016.[18] These data confirm that treatment of unconventional wastes at these three facilities diminished by 2012, while treatment of conventional waste and discharge of high salinity waters continued at consistent rates (Figure S1). Average annual discharge rates from 2012 to 2017 were of $236\pm61 \times 10^6$ L per year at the Franklin Facility and $174\pm29 \times 10^6$ L per year at the Josephine Facility.[28]

In each of the sites, effluents from the CWT facilities discharge to the local streams. The stream sediments in these areas are common to northern Appalachian watersheds. Grain size distribution analyses indicate that the stream sediments consistently range from 5-15% silt and clay across all streams. The remainder of the size fraction is fine to very coarse sand. Results in this study refer to the bulk sediments without analysis of selective grain-size fractions.

Sample Collection. Grab stream sediments were collected in May 2014 (Franklin n= 2, Josephine n=7, Hart n=2), June and August 2015 (Franklin n= 4, Josephine n=2, Hart n=2), and June 2017 (Franklin n= 4, Josephine n=3) from the three effluent sites. Approximately 100 grams of the top 2-4 cm of sediment were scooped with a shovel and stored in a polypropylene jar. Multiple sediment samples were similarly collected from various points upstream of the disposal site over the course of the sampling campaigns (Franklin n=5, Josephine n=7, Hart n=6). Upstream sediments are assumed to be

unaffected by effluents and therefore are used as reference sites. However, other upstream sources such as coal mine discharges and other CWT facilities could potentially influence the "background".

One effluent sample was also collected from the Franklin Facility in 2015. The sample was collected unfiltered, prior to coming in contact with stream water. The effluent was diluted with freshwater to a specific conductivity less than seawater (<50 mS/cm) and passed through two sequential plastic columns each containing 10 grams of MnO_2 coated acrylic fiber that efficiently adsorbs Ra.[29-36] The flow rate through the columns was monitored periodically and kept at less than 1 L/min. Fibers were rinsed with DI water, hand squeezed to remove particulates and excess moisture, and stored in separate plastic bags prior to laboratory processing.

Radionuclide Analyses. Approximately 40-60 grams of sediment were oven dried at 105 degrees C and, if necessary, ground with a mortal and pestle to a diameter less than 5 mm. Samples were packed and weighed in plastic snap close Petri style dishes (6.5 cm in diameter and 2 cm in height) that were then sealed with electrical tape and coated in wax to prevent the escape of gaseous ^{222}Rn ($t_{1/2}$ =3.8 days) and ^{220}Rn ($t_{1/2}$=55 seconds). The MnO_2 coated fibers from the Franklin Facility were compressed and then packaged and incubated similarly to the sediment samples. The two fibers were packaged and analyzed separately to monitor for potential Ra bleed through that would result in underestimation of Ra activities.[34]

Sealed samples incubated for a minimum of 21 days to allow ^{226}Ra to reach radioactive secular equilibrium (i.e. the activity of the parent nuclide is equal to the

187 activity of decay product) with ^{222}Rn along with other decay products, ^{214}Bi ($t_{1/2}$ = 19.9
188 minutes) and ^{214}Pb ($t_{1/2}$ = 27 minutes). This holding time also allows ^{228}Th to reach
189 radioactive secular equilibrium with ^{224}Ra ($t_{1/2}$=3.6 days) and the succeeding short-lived
190 radionuclides including ^{212}Pb ($t_{1/2}$=10.6 hours) and for ^{228}Ra to reach radioactive secular
191 equilibrium with its immediate decay product ^{228}Ac ($t_{1/2}$=6.1 hours). If radioactive secular
192 equilibrium is assumed in these sections of the U and Th decay series, ^{228}Ra, ^{226}Ra, and
193 ^{228}Th can be measured through their decay products [36-39] when direct measurement is not
194 feasible (e.g. the significant interference of ^{235}U (54% yield) on the 186 KeV peak).
195 Following incubation, samples were counted on a Canberra Broad Energy 5030
196 Germanium Gamma detector surrounded by 10 cm of lead shielding. Samples typically
197 counted for 6- 48 hours so that counting errors (2σ) were less than 10%. ^{226}Ra activities
198 were measured through the 351 KeV energy peak of ^{214}Pb. ^{228}Ra activities were
199 measured through the 911 KeV energy peak of ^{228}Ac. ^{228}Th activities were measured
200 through the 239 KeV energy peak of ^{212}Pb. Finally, ^{210}Pb ($t_{1/2}$ = 22 years) activities were
201 measured directly through the 47 KeV energy peak. The detector efficiencies were
202 determined using a U-Th reference ore material (DL-1a) prepared by the Canadian
203 Certified Reference Materials Project (CCRMP) that was packaged and incubated in a
204 container identical to the samples. Background and efficiency checks were performed
205 routinely prior to and during the time frame of sample analyses.
206 We accounted for attenuation of gamma photons by the sample itself at each
207 energy investigated in this study using U and Th point sources according to methods
208 described in Cutshall et al.[40] At low energies (<200 KeV; ^{210}Pb), differences in sample
209 density and composition between the standard and samples of interest resulted in

significant attenuation differences. However, we found at higher energies (>200 KeV), these differences were generally minor (i.e. within statistical counting error) for our sample set.

RESULTS AND DISCUSSION

Accumulation of Ra and decay products in sediments at OGW disposal sites. At all three investigated sites, we consistently find elevated Ra activities in stream sediments collected near effluent pipes at the outfall sites (^{226}Ra = 57-14,949 Bq/kg; n= 26) compared to upstream sediments (^{226}Ra = 9-41 Bq/kg; n=18) (Figure 2). Sediments from the Franklin effluent site had ^{226}Ra activities ranging from 269-14,949 Bq/kg (n=10), sediments the Josephine effluent site had ^{226}Ra activities ranging from 119- 10,747 Bq/kg (n=12), and sediments from the Hart effluent site had ^{226}Ra activities ranging from 57-351 Bq/kg (n=4). We did not observe any apparent trends in activities increasing or decreasing with time.

Because Ra is significantly higher in sediments from disposal sites compared to sediments from upstream sites (up to ~650 times compared to the average ^{226}Ra background activity at the Franklin Facility), combined with direct evidence for water contamination from OGW effluents in the stream water,[20, 41] we suggest that the CWT facility discharges are the source for the elevated Ra in the impacted stream sediments. While total Ra activities in conventional OGW can be found up to 250 Bq/L, low ^{226}Ra activities in the discharged effluents from Josephine site were reported by Warner et al[20] (0.13-0.19 Bq/L), which indicate substantial Ra removal as part of the CWT treatment. Similarly, we found relatively low activities of ^{226}Ra and ^{228}Ra (0.4 Bq/L and 0.6 Bq/L,

233 respectively) in effluents collected from the Franklin Site in 2015. In spite of the large
234 removal of Ra from the treated effluents, Ra in sediments collected from the disposal
235 sites was still elevated. These data suggest that the release of low Ra effluents can
236 potentially results in high Ra accumulation in sediments at the disposal sites. However,
237 we cannot exclude the possibility of infrequent pulses of high Ra effluents to the streams
238 as a major contributor to the Ra activities measured in sediments from the disposal sites.
239 We conducted mass-balance calculations to evaluate the possibility that the
240 ongoing release of low-Ra effluents is responsible for the elevated Ra observed in the
241 sediments near the effluents discharge sites. Our model (see SI for details) takes into
242 account the Ra loading to the stream (based on the Ra activities and volume of the
243 discharge effluents), variable salinity ranges that control the Ra adsorption coefficient
244 (K_d)[42], and the volume of impacted sediments. We find that the Ra activities in impacted
245 stream sediments modeled from these mass-balance calculations are similar to the
246 measured Ra activities in the sediments, supporting the notion that Ra accumulation at
247 the levels observed in this study is possible from long-term discharge of treated OGW
248 effluents even with low Ra activities. Our model does not account for any sediment
249 losses from the system due to continuous downstream transport. A previous study
250 estimated sedimentation rates at 5 to 8 cm per year in a location downstream of the
251 discharge site of Blacklick Creek[43], suggesting that there is likely some transport of
252 sediments to and from the discharge sites, which could effectively be "diluting" the Ra
253 activities at the discharge sites.
254 The retention of Ra in stream sediments following OGW disposal can be obtained
255 by (1) Ra adsorption to clays and/or manganese and iron oxides;[42, 44, 45] (2) incorporation

256 of Ra into secondary minerals such as barite ($(Ba,Ra)SO_4$) that could be generated upon
257 the blending of Ba-rich OGW with high-sulfate river water; [46] and/or (3) episodic or
258 ongoing addition of extremely fine-grained barite particles that were generated during the
259 treatment process, suspended in the liquid effluents, and then transported to the stream
260 sediments. While determining the mechanism of Ra accumulation to sediments is outside
261 the scope of this study, future research should investigate whether Ra is incorporated into
262 sediments in these streams through adsorption, authigenic barite formation, or effluent-
263 transported solid barite particles. Such a distinction could have important implications for
264 mitigating future contamination.

265 In addition to ^{226}Ra and ^{228}Ra, elevated activities of Ra decay products, ^{210}Pb and
266 ^{228}Th, were detected in the sediments collected from two CWT disposal sites at
267 substantially elevated activities compared to the upstream sediments (Figure 2).
268 Sediments from the Franklin site had ^{228}Th activities ranging from 91-4591 Bq/kg and
269 ^{210}Pb activities ranging from 117-1593 Bq/kg, and sediments the Josephine effluent site
270 had ^{228}Th activities ranging from 32- 2614 Bq/kg and ^{210}Pb activities ranging from 33-82
271 Bq/kg. Upstream ^{228}Th and ^{210}Pb activities ranged from 9-38 Bq/kg and 14-81 Bq/kg,
272 respectively, at both sites. Given the low solubility of Th and Pb and their negligible
273 levels in OGW[8], we assume that the accumulation of ^{228}Th and ^{210}Pb in the stream
274 sediments is likely due to Ra decay and subsequent ingrowth in situ, rather than the
275 transport and addition of these nuclides via retention from discharged effluents.
276
277 **Source and Age Constraints of Radionuclide Accumulation.** Determination of the
278 timing of Ra accumulation has important implications for assessing the source of Ra

279 contamination in the investigated streams. If elevated Ra activities are found to be solely
280 due to legacy contamination from Marcellus OGW treatment and disposal, then the end
281 of this practice in 2011 should have prevented any additional contamination from OGW
282 disposal after 2011. However, if the age of the contamination is relatively recent, then
283 the elevated Ra activities in stream sediments at the disposal sites can be attributed to
284 continued disposal of treated conventional OGW.

285 The $^{228}Th/^{228}Ra$ activity ratios have been previously used to determine the age and
286 source of OGW spills and radioactive barite associated with oil and gas development.[38, 47, 48]
287 Unsupported ^{228}Ra decays into ^{228}Th, and the $^{228}Th/^{228}Ra$ activity ratio can serve as a
288 chronometer of contamination events[8, 38, 47, 49] due to the insolubility and suitable 1.9 year
289 half-life of ^{228}Th.[45, 50-52] With time, ^{228}Th approaches transient equilibrium with ^{228}Ra,
290 and the $^{228}Th/^{228}Ra$ activity ratio will approach ~1.5 after about 15 years. Changes in the
291 $^{228}Th/^{228}Ra$ activity ratio with time can be modeled according the Equation 1.

292 $$\frac{228Th}{228Ra} = \frac{\lambda_{Th228}}{\lambda_{Th228}-\lambda_{Ra228}}\left[1 - e^{(\lambda_{228Ra}-\lambda_{Th228})t}\right] \quad \text{(Eq. 1)}$$

293 Previous studies have typically employed this $^{228}Th/^{228}Ra$ dating technique on
294 relatively specific events,[38, 47, 48] while its application to dating contamination events
295 derived from OGW effluents that have been released over multiple years is less
296 established. Here we develop the use of the ^{228}Th-^{228}Ra disequilibrium to constrain the
297 age of ongoing contamination from discharging effluents. If all the excess Ra measured
298 in the sediments from the disposal sites was solely accumulated between 2008 and 2011,
299 when the Marcellus OGW was discharged, then observed $^{228}Th/^{228}Ra$ activity ratios
300 would fall within the range of 0.8-1.2 in 2015 and 1.1-1.3 in 2017 (Figure 3). However,
301 the relatively low $^{228}Th/^{228}Ra$ activity ratios (0.3-0.7 in 2015 and 0.2-0.4 in 2017) found

in impacted sediments at the Franklin and Josephine sites indicate that at least a portion of the measured Ra has accumulated during the ~0.5 to 3 years prior to sample collection. These relatively low $^{228}Th/^{228}Ra$ activity ratios observed in the stream sediments rule out the possibility that the elevated Ra activities in the sediments is entirely derived from legacy contamination from documented Marcellus OGW, and rather suggests that at least a portion of the excess radioactivity in sediments from the disposal sites is derived from recent disposal of conventional OGW.

$^{228}Th/^{228}Ra$ age dating assumes a closed system with no losses of ^{228}Ra or external source of ^{228}Th in the impacted sediments. Adsorption/desorption is heavily controlled by the ionic strength of the fluid, among other parameters such as pH and the cation exchange capacity (CEC) of the sediment.[42, 44, 45, 53] For example, in groundwater systems, the sediment partition coefficient (K_d; the ratio of the adsorbed nuclide to the nuclide in the dissolved phase) for Ra exponentially increased from 1.4 at TDS~200,000 mg/L to >500 at TDS<1000 mg/L.[42] We posit that the dilution of highly saline OGW with stream water following discharge permits Ra adsorption to stream sediment. Subsequent desorption of Ra or ingrown ^{228}Th is possible following fluctuations in salinity or pH. However, Th is far less mobile than Ra,[52, 54] and losses to the system from desorption would more heavily affect Ra rather than Th. In such a case, the $^{228}Th/^{228}Ra$ activity ratios measured in this study would be artificially high and derived age constraints would be artificially old (i.e., indicating even younger ages than our evaluation assuming no Ra lost). Additionally, $^{228}Th/^{228}Ra$ age dating in this system assumes a fixed sediment substrate despite potential transport of sediments downstream. Regardless, the results from this study indicate that contamination has occurred on a

recent time scale and cannot solely be attributed to discharges of Marcellus OGW from 2008-2011.

Age constraints determined from the $^{228}Th/^{228}Ra$ activity ratios can be corroborated with $^{228}Ra/^{226}Ra$ activity ratios, which also suggest that Ra is being continually introduced to the stream sediments from the disposal of conventional OGW. While distinctly low $^{228}Ra/^{226}Ra$ activity ratios (typically less than 0.3) characterize OGW from the Marcellus Shale, higher $^{228}Ra/^{226}Ra$ (~1) activity ratios have been reported for OGW from conventional formations.[6, 7, 55] The $^{228}Ra/^{226}Ra$ activity ratios in the impacted sediments are expected to mimic the ratios of the OGW, combined with the decay of ^{228}Ra over time. Following the retention of Ra to the stream sediments, unsupported ^{228}Ra decays with a half-life of 5.8 years, while ^{226}Ra is relatively unchanged over this time scale. Therefore, the $^{228}Ra/^{226}Ra$ activity ratio in contaminated sediment is expected to decrease with time according the Equation 2, where lambda is the ^{228}Ra decay constant (0.12 yr^{-1}) and t is time.

$$\frac{228Ra}{226Ra} = \left(\frac{228Ra}{226Ra}\right)_o e^{-\lambda_{Ra228}t} \qquad \text{(Eq.2)}$$

Therefore, if all excess Ra was accumulated in the sediments during the period of Marcellus OGW disposal (2008 to 2011), we would expect $^{228}Ra/^{226}Ra$ activity ratios to be well below 0.3 as ^{228}Ra decays with time. Instead, we observed $^{228}Ra/^{226}Ra$ activity ratios ranging from 0.4-0.9 in sediments collected in 2015 and 2017, which are higher than typical Marcellus $^{228}Ra/^{226}Ra$ ratios (< 0.3), suggesting that Ra in the sediments was derived from relatively recent conventional OGW with a relatively high $^{228}Ra/^{226}Ra$ activity ratio of ~1 (Figure 4).

Policy Implications for Disposal of Conventional OGW from CWT Facilities.

Previous[20] and new data presented in this study indicate that the disposal of OGW to the environment results in the accumulation of Ra and Ra-decay products in the upper section of impacted stream sediments. Our data indicate that in spite of the removal of a large fraction of Ra from treated OGW, the discharge of effluents results in accumulation of Ra (^{226}Ra up to 15,000 Bq/kg) in impacted sediments. This observation is supported by a Ra mass-balance model (See SI for details) that shows that the modeled Ra accumulation in the stream sediments is similar to the observed Ra activities in the impacted sediments. While there is no federal regulation, several states have developed limits for solids containing NORM, which typically range from 185-1850 Bq/kg (5 pCi/g to 50 pCi/g).[56] Our data indicate that the disposal of treated OGW results in elevated NORM activities in impacted stream sediments above the 1850 Bq/kg threshold. Waste materials with ^{226}Ra above 1850 Bq/kg should be transferred to a licensed radioactive waste disposal facility that has strict requirements related to site location and the following features: (1) lined walls, back up lining, and a cover, (2) a leachate collection system, and (3) leak detector systems.[57]

Relatively low ^{228}Th/^{228}Ra and high ^{228}Ra/^{226}Ra activity ratios measured in sediments collected from two CWT discharge sites in PA indicate that at least a portion of the Ra measured in sediments has accumulated in recent (0.5-3) years when no Marcellus OGW was reportedly discharged, suggesting that conventional OGW discharges are a noteworthy source of radium accumulation. Accordingly, data from this study indicate that restricting treatment to only conventional OGW at CWT facilities does not prevent the large accumulation of Ra in stream sediments from disposal sites. Our

371 data and previous data[20] also suggest that the large Ra removal from the disposed
372 effluents potentially does not mitigate the high NORM accumulation in sediments at the
373 disposal sites, although we cannot rule out the possibility of infrequent pulses of high-Ra
374 effluents as a major contributor of Ra to the sediments rather than long-term discharge
375 and accumulation from low-Ra effluent.

376 In addition to treatment at wastewater treatment plants, unconventional OGW is
377 also prohibited from being used as a deicing agent or dust suppressant on roads, while
378 untreated conventional OGW is permitted for application to roads.[26] While the fate of
379 NORM following the use of OGW as deicing agents and dust suppressants remains a
380 major question, data from this study suggests that permission of conventional OGW will
381 not protect the environment from radioactive contamination. In an initial assessment,
382 Skalak et al. [26] found elevated Ra (1.2x), Sr, Ca, and Na in roadside sediments in Vernon
383 County, PA, where OGW was applied to roads for dust suppression when compared to
384 background sites. Future research addressing the application of OGW to roads as a
385 deicing agent and dust suppressant is important to fully understand the impact of OGW
386 related NORM on soils and sediments and the human and environmental health
387 implications of this practice.

388 Overall, this study shows consistently elevated activities of Ra and their decay
389 products in stream sediments at three disposal sites of CWT facilities in PA receiving
390 conventional OGW, up to five years after unconventional Marcellus OGW were no
391 longer discharged. The $^{228}Th/^{228}Ra$ and $^{228}Ra/^{226}Ra$ activity ratios in the sediments
392 suggest that at least a portion of the Ra has accumulated in recent years when no
393 Marcellus OGW were reportedly discharged, indicating that permitting CWT facilities to

394 treat and release only conventional OGW does not prevent radioactive contamination and
395 accumulation in the upper portion of sediments at disposal sites. In order to prevent
396 radionuclide accumulation in the environment, we suggest that disposal restrictions
397 should apply to any type of Ra-rich water, regardless of source, and that current policies
398 differentiating the treatment and disposal of conventional OGW from unconventional
399 OGW should be reconsidered.
400

401 **ACKNOWLEDGEMENTS**

402 We thank Andrew Kondash for fieldwork assistance and Dr. James Kaste for
403 laboratory use at the College of William and Mary. The authors also gratefully
404 acknowledge funding from the Park Foundation and NSF (EAR-1441497). We thank four
405 anonymous reviewers for their comments and insights who greatly improved the quality
406 of this manuscript.
407

408 **SUPPORTING INFORMATION AVAILABLE**

409 Expanded information on the Ra mass balance calculations, 1 figure, and 1 table
410 are available.
411
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Figures

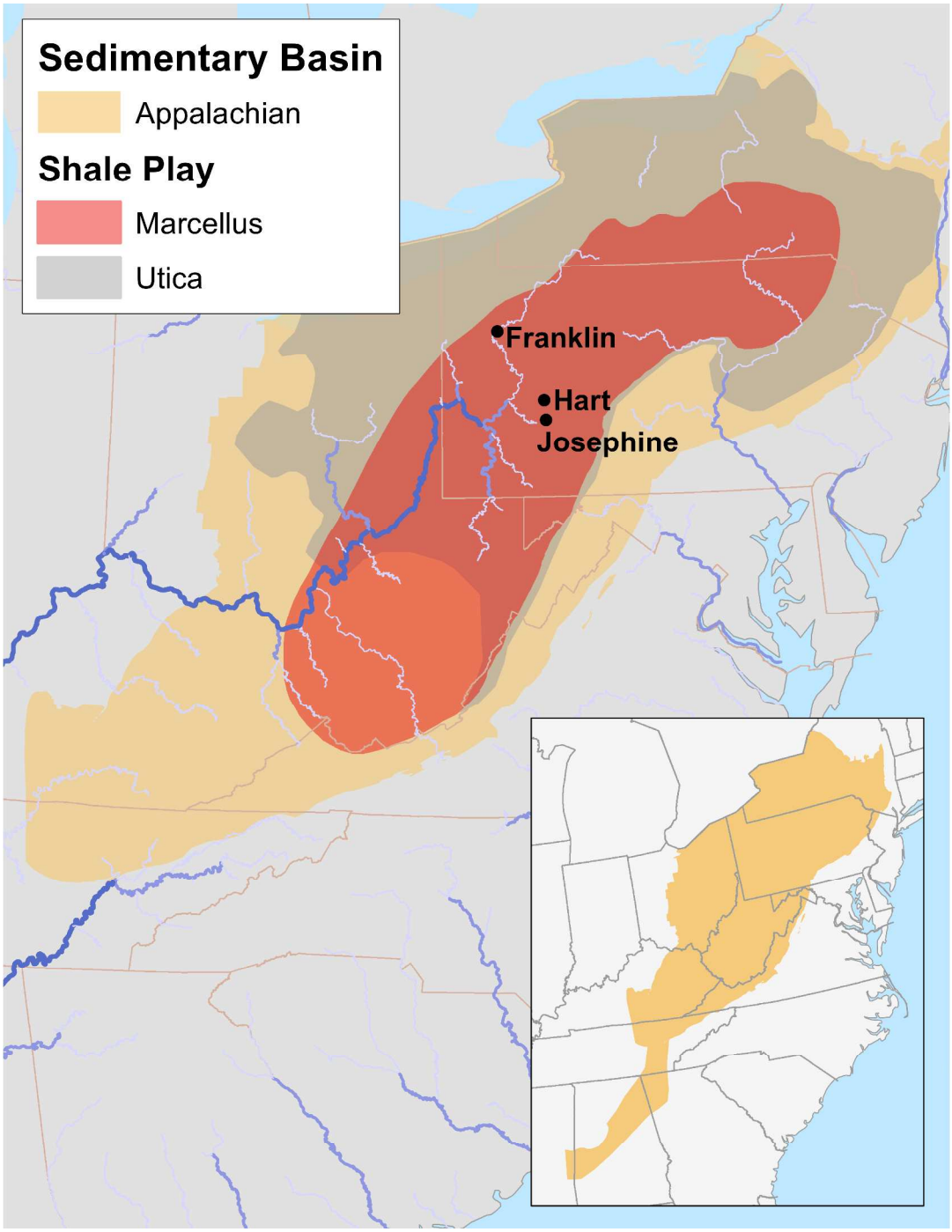

Figure 1. A map of the northern Appalachian Basin and major shale plays in the eastern United States. Inset map shows the entirety of the Appalachian Basin, that extends from New York southward through Pennsylvania, Maryland, Ohio, West Virginia, Virginia, Kentucky, and Tennessee before terminating in Alabama. The location of the three CWT facilities investigated in this study are also shown.

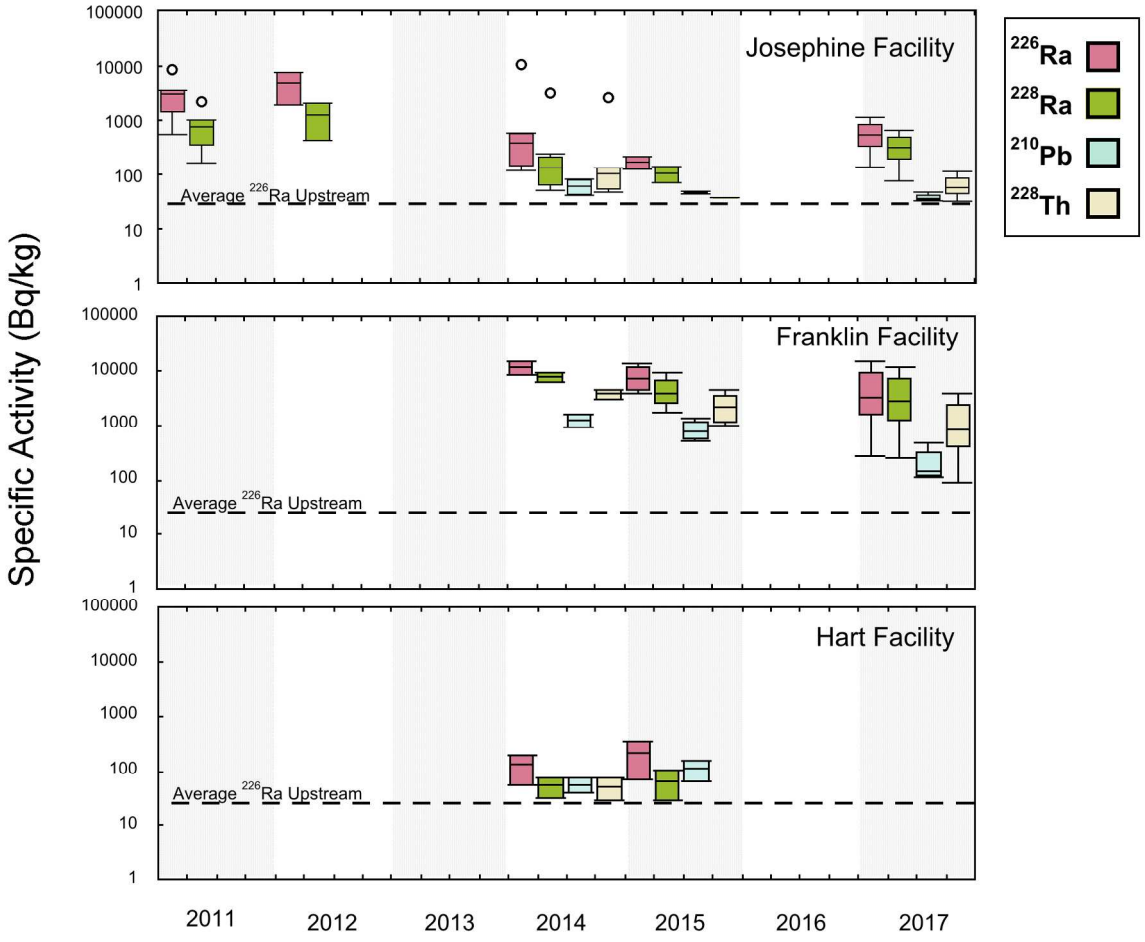

Figure 2. ^{226}Ra, ^{228}Ra, ^{210}Pb, and ^{228}Th in sediments collected from three streams receiving OGW discharged by CWTs in 2014, 2015, and 2017. Josephine data from 2011 and 2012 were compiled from the literature.[18] The boxplots indicate the middle 50% and the median of the data. Boxplot whiskers indicate the minimum and maximum values, excluding outliers which are indicated by open circles. Dashed lines show the average ^{226}Ra activity of upstream samples, assumed to be unaffected by treated OGW effluents. Elevated activities were measured at all three effluent sites compared to upstream sites.

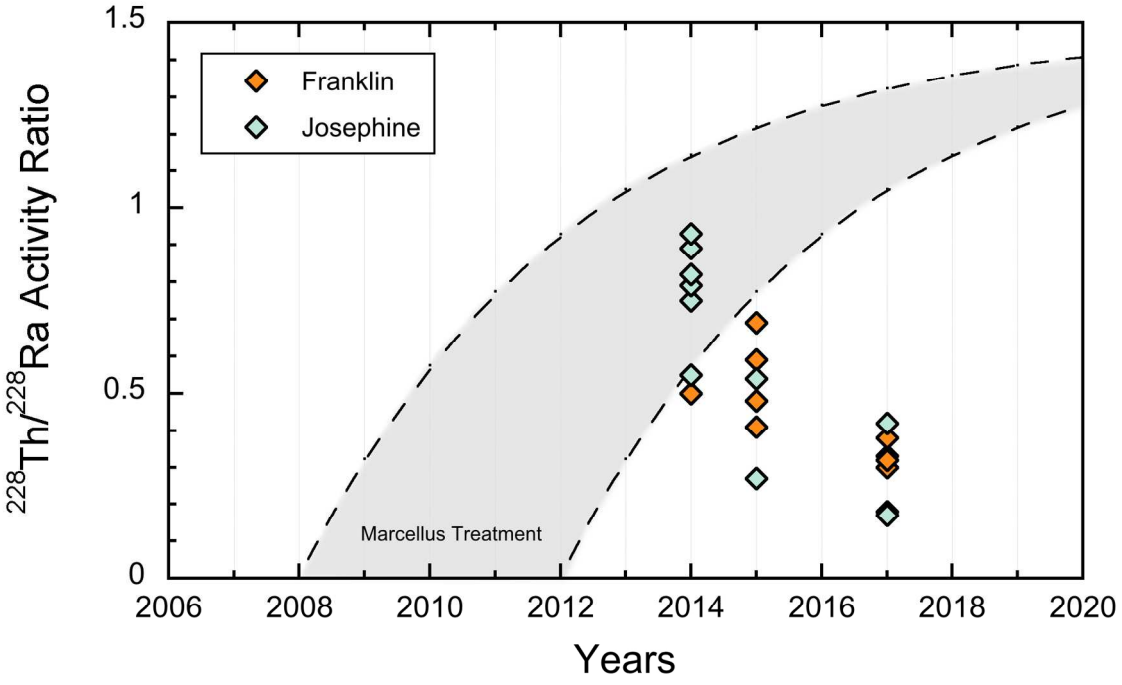

Figure 3. $^{228}Th/^{228}Ra$ activity ratios in sediments collected from the Franklin and Josephine CWT facilities in 2014, 2015, and 2017. Ratios that fall within the gray band reflect contamination that can be dated to the time period of high discharges of treated unconventional Marcellus OGW (2008-2011). Sediments collected in 2015 and 2017 had $^{228}Th/^{228}Ra$ activity ratios that fall below the expected range if contamination was solely from Marcellus OGW contamination. These relatively low ratios suggest that at least a portion of the Ra that has accumulated in the sediments is from relatively recent releases of conventional OGW.

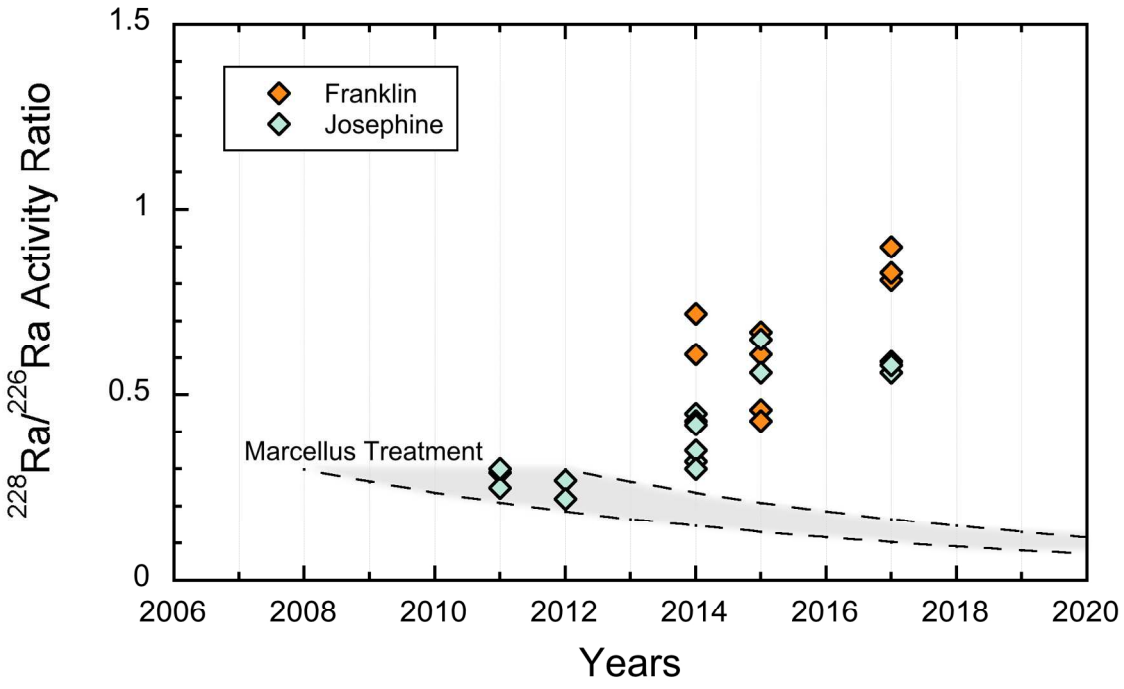

Figure 4. ^{228}Ra/^{226}Ra activity ratios in sediments collected from the Franklin and Josephine CWT facilities in from 2011-2017. 2011 and 2012 data are compiled from Warner et al. (2013).[20] Ratios that fall within the gray band reflect the ratios that would be expected from Marcellus OGW contamination from 2008-2011. Sediments from this study collected in 2014, 2015 and 2017 had ^{228}Ra/^{226}Ra activity ratios above the Marcellus range, suggesting that at least some of the contamination is sourced from conventional OGW with a relatively higher ^{228}Ra/^{226}Ra activity ratio (~1).

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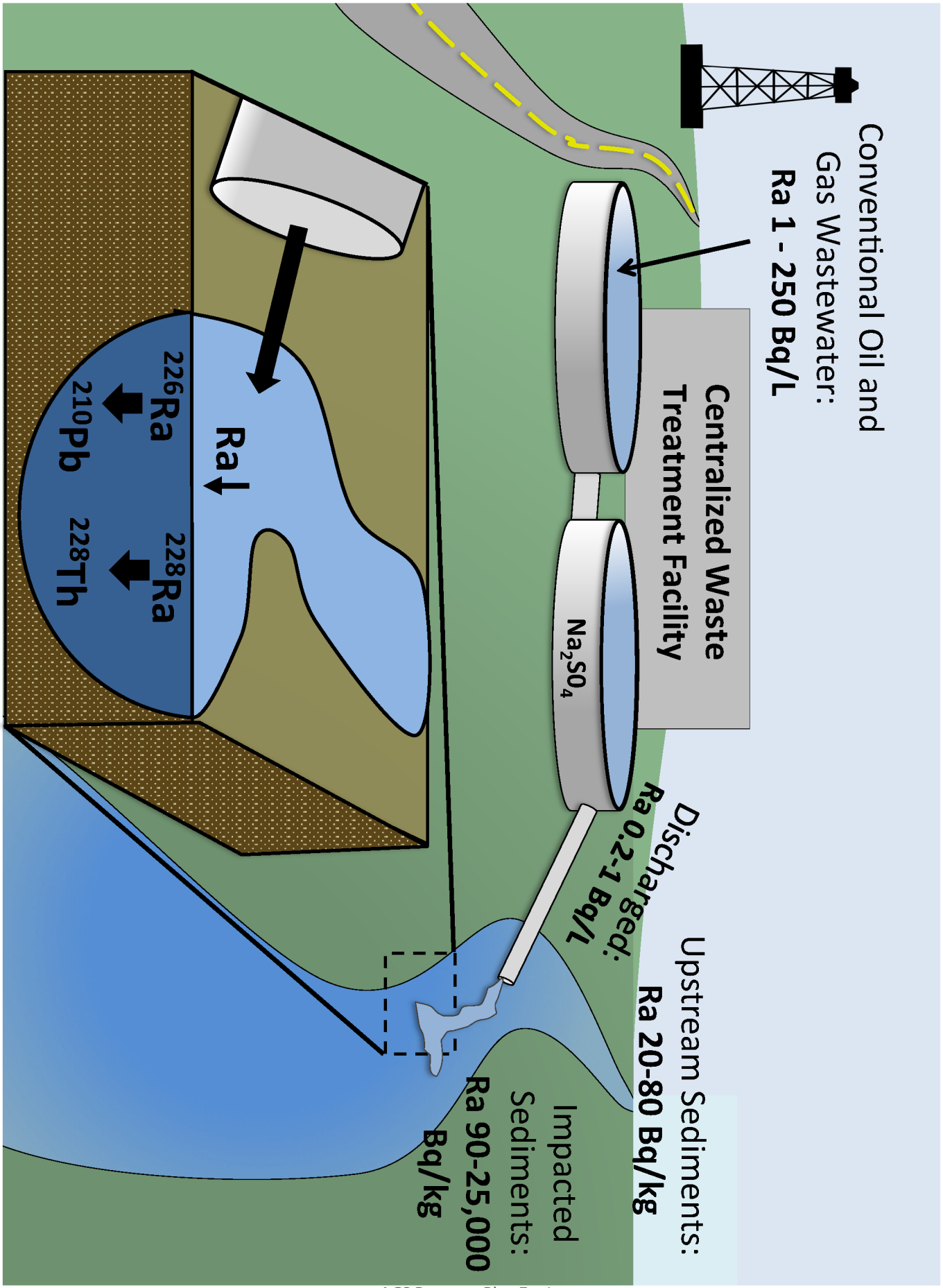
Conventional Oil and Gas Wastewater:
Ra 1 - 250 Bq/L
Centralized Waste Treatment Facility
Na_2SO_4
Discharged:
Ra 0.2-1 Bq/L
Upstream Sediments:
Ra 20-80 Bq/kg
Impacted Sediments:
Ra 90-25,000 Bq/kg
Ra
^{226}Ra
^{210}Pb
^{228}Ra
^{228}Th

Executive Summary; Contaminant Characterization of Effluent from Pennsylvania Brine Treatment Inc., Josephine Facility Being Released into Blacklick Creek, Indiana County, Pennsylvania

Implications for Disposal of Oil and Gas Flowback Fluids from Brine Treatment Plants

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Affiliation: Center for Healthy Environments and Communities (CHEC), Department of Environmental and Occupational Health, Graduate School of Public Health, University of Pittsburgh

Revised Report Date: March 25, 2011

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This report is being widely disseminated to local, state and federal public health and regulatory authorities, municipal water authorities, and policymakers, because there is sufficient evidence that recreationalists and private well water users may reasonably be exposed to identified contaminants in the effluent discharge, and that downstream water intakes be made aware of potential impacts to water sources from these discharges, and act accordingly.

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The concentrations of analyzed contaminants in this effluent of primary environmental public health importance, which may also stress aquatic life, include: barium (Ba) [mean, 27.3 ppm; maximum, 37.0 ppm]; bromides (Br) [mean, 1068.8 ppm; maximum, 1100.0 ppm; strontium (Sr) [mean, 2983.1 ppm, maximum 3120.0 ppm]; benzene [mean 0.012 ppm; maximum 0.013 ppm] and 2

butoxyethanol (2-BE) [mean 59ppm; maximum 66 ppm]. Contaminant concentrations of ecological and secondary drinking water importance include: chlorides (Cl) [mean 117,625 ppm, maximum 125,000 ppm]; magnesium (Mg) [mean 1247.5 ppm; maximum 1300.0 ppm]; total dissolved solids (TDS) [mean 186,625 ppm; maximum 190,000 ppm]; sulfate (SO4) [mean 560 ppm; maximum 585 ppm], and pH [mean 9.58 units; maximum 10 units].

Comparisons of Effluent Contaminant Concentrations to Standards, Guidelines and Criteria set by Federal and State Regulatory and Investigative Agencies for the Protection of Human and Aquatic Health

Levels of contaminants in effluent from the PBT- Josephine Facility were interpreted according to comparisons with applicable federal and state standards and recommended guidelines for both human and aquatic health. Refer to Table 3, Federal and State Recommendations and Standards for Concentrations of the Analytes Sampled in PA Brine Josephine Effluent and Table 4, Derived Minimum Risk Levels (MRL's) for Ingestion of Contaminants through Drinking Water Sources for a complete list of comparison values by contaminant.

Barium - Barium had a mean concentration in effluent of 27.3 ppm (maximum of 37 ppm); this is approximately 14 times the United States Environmental Protection Agency (EPA) maximum concentration limit (MCL) of Ba in drinking water of 2 ppm. The EPA consumption concentrations 'water and organism' and 'organism alone' for barium are both 1 ppm. The levels of barium in the effluent are over 27 times these consumption concentrations. The U.S. EPA criteria maximum concentration (CMC) and the EPA criteria continuous concentration (CCC), both for protection of aquatic health, are 21 ppm and 4.1 ppm, respectively; the mean level of barium in effluent exceeds these criteria by 1.3 and 6.7 times, respectively. The mean concentration of barium in PBT-Josephine effluent water (27.3 ppm) is 3.96 times the derived drinking water MRL for intermediate and chronic exposures for adult men; 4.73 times the derived drinking water MRL for intermediate and chronic exposures for adult women; and 8.98 times the derived drinking water MRL for intermediate and chronic exposures for children.

Strontium - The EPA recommended MCL for Sr in finished municipal drinking water is 4 ppm. The mean concentration of Sr in PBT-Josephine effluent water is 2,981.1 ppm (over 745 times the recommended MCL). The strontium ATSDR MRL for oral route, intermediate exposure is 2 mg/kg of body mass/day, for

musculoskeletal endpoints. The derived minimum risk levels for strontium in drinking water for intermediate exposure for adult men, adult women, and children are 68.87 mg/L/day, 57.67 mg/L/day, and 30.45 mg/L/day, respectively. The mean concentration of strontium in PBT-Josephine effluent water (2,981.1 ppm) is 43.29, 51.68 and 97.90 times the derived strontium drinking water MRL's for intermediate exposures for adult men, adult women, and children, respectively. The maximum level of strontium leaving the outfall into Blacklick Creek was 3,120 ppm; this concentration is 45.30, 54.10, and 102.46 times the derived strontium drinking water MRL's for adult men, adult women, and children, respectively.

Strontium is not listed on the PBT-Josephine Facility NPDES permit but the facility is required to notify the PA DEP if they routinely discharge 100 ppb of a toxic pollutant or nonroutinely discharge 500 ppb of a toxic pollutant. The mean concentration of Sr in effluent water of 2,981.1 ppm is 29,811 and 5,962 times the lower and upper notification levels required by the PA DEP NPDES permit, respectively. Searches of the PA DEP file for December, 2010, which is contained in Appendix A shows no such notification to the DEP.

Bromide - Bromide in water is of concern because of its ability to form brominated analogs of drinking water disinfection by-products (DBP). Specifically, bromide can be involved in reactions between chlorine and naturally occurring organic matter in drinking-water, forming brominated and mixed chloro-bromo byproducts, such as trihalomethanes or halogenated acetic acids. Several DBPs have been linked to cancer in laboratory animals, and as a result the U.S. EPA has regulated some DBP's. There is general agreement that bromide levels in fresh-water sources be kept below about 100 ppb (.1 ppm) so that formation of brominated DBP's are minimized, therefore regulatory authorities and water treatment plant operators become concerned when there are sources of bromides in a surface water system adding to this level. The PBT- Josephine facility discharged effluent into Blacklick Creek with a measured mean concentration of bromide of 1,068.8 ppm, which is 1,068,800 ppb. This is 10,688 times the 100 ppb level at which authorities become concerned.

Bromide is not listed on the PBT-Josephine Facility NPDES permit but the facility is required to notify the PA DEP if they routinely discharge 100 ppb of a toxic pollutant or nonroutinely discharge 500 ppb of a toxic pollutant. The mean concentration of Br in effluent water 1,068.8. ppm is 10,688 and 2,138 times the

lower and upper notification levels required by the PA DEP NPDES permit, respectively. Searches of the PA DEP file for December, 2010, which is contained in Appendix A shows no such notification to the DEP.

Benzene - The mean level of benzene, a known carcinogen, in outfall effluent from PBT-Josephine was 0.012 ppm or 12 ppb. The drinking water MCL for benzene is 5 ppb, thus effluent levels were above twice the drinking water MCL. The EPA consumption, water and organism risk level for benzene is 2.2 ppb in water, the mean level of benzene in PBT-Josephine effluent water is almost 6X this criteria; the organism only risk level for benzene is 50 ppb in water, the mean level of benzene in effluent water is 24% of this guideline. The benzene ATSDR MRL for oral route, chronic exposure is 0.0005 mg/kg of body mass/day, for immunological endpoints. The derived minimum risk levels for benzene in drinking water for chronic exposure for adult men, adult women, and children are 0.017 mg/L/day, 0.014 mg/L/day, and 0.008 mg/L/day, respectively. The mean concentration of benzene in PBT-Josephine effluent water (0.012 ppm) is 70% of, 86% of, and 1.5 times the derived chronic drinking water MRL for benzene for adult men, adult women, and children, respectively.

2-butoxyethanol - 2-butoxyethanol is a glycol ether and is used as an anti-foaming and anti-corrosion agent, as well as an emulsifier in slick-water formulations for Marcellus Shale gas extraction. The mean and maximum levels of 2-BE found in the PBT – Josephine effluent were 59 ppm and 66 ppm, respectively. The 2-BE ATSDR MRL for oral route, acute exposures is 0.4 mg/kg/day based on hematological effects, with an uncertainty factor of 90; the 2-BE MRL for oral route, intermediate exposure is 0.07 mg/kg/day and it is based on hepatic health endpoints with an uncertainty factor of 1000. The derived minimum risk levels for 2-BE in drinking water for acute exposure for adult men, adult women, and children are 13.77 mg/L/day, 11.53 mg/L/day, and 6.09 mg/L/day, respectively; the derived MRL's for 2-BE in drinking water for intermediate exposure for adult men, adult women, and children are 2.41 mg/L/day, 2.02 mg/L/day, and 1.07 mg/L/day, respectively.

The mean concentration of 2-BE in PBT-Josephine effluent water (59 ppm) is 4.28, 5.12, and 9.69 times the derived 2-BE drinking water MRL's for acute exposure to adult males, adult females, and children, respectively. The mean concentration of 2-BE in PBT-Josephine effluent water is 24.48, 29.21, and 55.14

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Other Contaminants - Contaminants with secondary MCL's (SMCL) and aquatic receptor effects that were measured in the PBT-Josephine Facility effluent include magnesium, manganese, chlorides, sulfates, and total dissolved solids (TDS). Magnesium was found in the effluent with a mean concentration of 1,247.5 mg/L, which is 24,950 times the EPA Mg SMCL of .05 mg/L. The mean concentration of Manganese in the effluent was .08 mg/L, and the SMCL for Manganese concentration in drinking water is .05 mg/L, which is 62.5% lower than the concentration in the effluent. The mean concentration of chlorides in the sample analysis was 117,625 mg/L, which is 470.5 times the SMCL for chlorides in drinking water of 250 mg/L. To protect aquatic communities, the criteria maximum concentration (CMC) for chlorides in surface water is 860 mg/L, and the criteria continuous concentration (CCC) for chlorides in surface water is 230 mg/L. The mean concentration of chlorides measured in samples was 138 times the CMC and 511 times the CCC. The mean concentration of sulfates in the sample analysis was 560 mg/L - 2.2 times the SMCL for sulfates in drinking water (250 mg/L). The SMCL for total dissolved solids (TDS) in drinking water is 500 mg/L, and the mean concentration of TDS measured in samples was 186,625 mg/L, 373 times the SMCL.

Masses of Contaminants Entering Blacklick Creek

CHEC has information from the Pennsylvania, Department of Environmental Protection (DEP) that the PBT – Josephine Facility treated 15,728,241 gallons of oil and gas wastewater in the 6 month period from July 1, 2010 to December 31, 2010. Using this figure as the amount of effluent wastewater exiting the Josephine outfall and using the mean level of each contaminant found in the effluent over the sampling period of the study, the masses of contaminants with important human and ecological consequences discharged from the PBT,

Josephine Facility into Blacklick Creek in the last 6 months of 2010 are projected to be: barium - 1627 kg (3588 pounds); strontium - 177,712 kg (391,856 pounds; 196 tons); bromides -63,708 kg (140,476 pounds; 70.2 tons); chloride – 7,011,631 kg (15, 460,646 pounds; 7,730 tons); sulfate – 33,382 kg (73,607 pounds; 36.8 tons); 2 butoxyethanol – 3517 kg (7,755 pounds; 3.88 tons); and total dissolved solids – 11,124,733 kg (24,530,036 pounds; 12,265 tons).

Potentially Exposed Populations

Recreationalists are at high risk of being exposed to outfall contaminants through ingestion, inhalation and through dermal exposure. While the pH of outfall water will not cause irreversible eye damage at the maximum observed level of 10 pH units, irritation of the eyes and mucous membranes may occur. The outfall of the Josephine Facility is easily accessible to users of nearby rails-to-trails pathways, and there are indications that anglers frequent the area.[1] Additionally, children wade and swim in the creek during warmer weather, and regional watershed websites indicate that paddlers use the creek for canoeing and kayaking. 2 BE released into Blacklick Creek may be ingested by swimmers in the creek. This pollutant can become airborne and present an inhalation hazard to anglers, swimmers and boaters. It is also taken in to the body via dermal absorption. Anglers catching and eating fish from upstream or downstream of the effluent outfall are at risk for exposure to multiple contaminants that were sampled in this study.

CHEC has developed maps showing numerous private water wells in the immediate vicinity of Blacklick Creek downstream from the effluent discharge. Private well water users are at risk of exposure to contaminants in effluent being released into Blacklick Creek because these private wells may capture water from the creek when the well pump rate is sufficiently high. High pump rates can occur especially during peak usage by residents.

The first identified municipal drinking water intake downstream of this discharge is at Freeport, Pennsylvania on the Allegheny River. Populations served by the Freeport authority and water authorities downstream of Freeport are at potential risk for exposure to contaminants identified in effluent, as well as other contaminants in Marcellus Shale flowback water that were not sampled for in this study.

[1] Blacklick Creek is classified as a 'trout stocking" stream.

Implications of Effluent Discharge from the PBT – Josephine Facility Discharge for Exposures to Other Contaminants Known to be Present in Marcellus Shale Flowback Fluids and a Regional Appreciation of These Results

Of particular environmental public health significance is that Marcellus Shale flowback water contains other contaminants, in addition to those analyzed for in this study, which have health consequences if ingested, inhaled, and/or absorbed through the skin. While we make no statements regarding the presence of other contaminants in this effluent water being discharged into Blacklick Creek, it is imperative that additional testing be conducted immediately by federal and state health and enforcement agencies to determine if other contaminants of public health significance are entering this watershed.

Additionally, oil and gas wastewater and Marcellus shale flowback fluids are being disposed of in "brine treatment" facilities and at Publically Owned Treatment Works (POTW's) throughout the Commonwealth of Pennsylvania and in Ohio, West Virginia, and New York. The ramifications of disposal of large quantities of oil and gas wastewater through ineffectual brine treatment plants and POTW's needs further evaluation throughout the region to determine its impact on stream and river systems and public drinking water supplies, as well as to recreationalists and private well water users.

Recommendations

- The Pennsylvania Brine Treatment – Josephine Facility is discharging up to 60 ppm of 2-BE into Blacklick Creek, which is not listed in its NPDES discharge permit. Other contaminants of human health importance found in effluent but not present on the permit also include bromide, benzene and strontium. Operations at this plant should be halted until all contaminants of human and aquatic health concern in accepted oil and gas fluids are known and it can be determined that the treatment processes used at the plant effectively remove these contaminants from the fluids being treated. The PA DEP should reevaluate the permit given to this operator as it clearly allows for chlorides and total dissolved solids to be discharged at levels exceeding aquatic health criteria.
- All approaches to the effluent discharge area and a reasonable distance downstream (at least 100 meters) from streamside and landside should be posted with warning signs. These signs should discourage any use of and/or contact with stream water.

- An advisory to all anglers should be issued stating that fish taken from this stream, both up and down stream may be contaminated in order to discourage fish take and consumption.
- Studies to determine the levels of all potential Marcellus Shale flowback fluid contaminants in downstream water, sediments and pore water should be undertaken immediately. These should include sampling upstream of the effluent discharge point and at short, intermediate and longer distances downstream from the effluent discharge point. The number of samples (n) of surface water, sediments and pore water upstream and at the various distances downstream should be sufficient so that statistically significant differences of contaminant concentrations can be inferred.
- Residential and other private well water users downstream of the effluent outfall of the PBT-Josephine Facility should be advised that there may be contaminants in their well water and discouraged from using it for drinking, cooking or bathing until such water is tested for continuous safe use. Therefore, it is imperative that well water from wells in close proximity to Blacklick Creek should be tested to assure that contaminants in Marcellus Shale flowback fluids and other oil and gas waste fluids are not present in concentrations that may affect human health.
- Municipal water authorities downstream of this outfall should be notified of the contaminants found in effluent from the PBT- Josephine Facility, of other possible contaminants in Marcellus Shale flowback fluids and oil and gas wastewater, and that there are other treatment facilities and POTW's in the Blacklick, Conemaugh, and Kiskiminetas drainages that accept and discharge oil and gas waste fluids into surface water. Downstream municipal water authorities should test raw unfinished intake water and finished drinking water for these contaminants that have been identified in effluent from the PBT- Josephine Facility, and other contaminants known to be present in Marcellus Shale flowback fluids and oil and gas wastewater.
- All municipal water authorities at reasonable distances downstream of "brine treatment" and POTW's accepting Marcellus Shale flowback fluids and other oil and gas wastewater in the region extending eastward across Ohio, Pennsylvania and West Virginia and New York should be notified of these results. It is important that they initiate sampling of raw, unfinished inflow water and finished drinking water immediately to ensure that their systems are capable of handling all potential contaminants, without breakthrough above specific drinking water MCL's or ATSDR derived MRL's.

- The PA DEP and other state and federal regulatory authorities should immediately review all surface water discharge permits granted to brine treatment facilities and POTW's that accept Marcellus Shale flowback fluids and oil and gas wastewater, to ensure that 2-BE concentrations being discharged are below all applicable standards, guidelines and criteria. This review should be informed by results of this report but should be extended to all known contaminants in flowback and other oil and gas wastewater.

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Table of Contents

List of Tables

List of Figures

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2-BE drinking water MRL's for intermediate exposure to adult males, adult females, and children, respectively.

2-BE is not listed on the PBT-Josephine Facility NPDES permit, but the facility is required to notify the PA DEP if they routinely discharge 100 ppb of a toxic pollutant or nonroutinely discharge 500 ppb of a toxic pollutant. The mean concentration of 2-BE in effluent water is 590 and 118 times the lower and upper notification levels, required by the PA DEP NPDES permit, respectively. Searches of the PA DEP file for December, 2010, which is contained in Appendix A, shows no such notification to the DEP.

Other Contaminants - Contaminants with secondary MCL's (SMCL) and aquatic receptor effects that were measured in the PBT-Josephine Facility effluent include magnesium, manganese, chlorides, sulfates, and total dissolved solids (TDS). Magnesium was found in the effluent with a mean concentration of 1,247.5 mg/L, which is 24,950 times the EPA Mg SMCL of .05 mg/L. The mean concentration of Manganese in the effluent was .08 mg/L, and the SMCL for Manganese concentration in drinking water is .05 mg/L, which is 62.5% lower than the concentration in the effluent. The mean concentration of chlorides in the sample analysis was 117,625 mg/L, which is 470.5 times the SMCL for chlorides in drinking water of 250 mg/L. To protect aquatic communities, the criteria maximum concentration (CMC) for chlorides in surface water is 860 mg/L, and the criteria continuous concentration (CCC) for chlorides in surface water is 230 mg/L. The mean concentration of chlorides measured in samples was 138 times the CMC and 511 times the CCC. The mean concentration of sulfates in the sample analysis was 560 mg/L - 2.2 times the SMCL for sulfates in drinking water (250 mg/L). The SMCL for total dissolved solids (TDS) in drinking water is 500 mg/L, and the mean concentration of TDS measured in samples was 186,625 mg/L, 373 times the SMCL.

Masses of Contaminants Entering Blacklick Creek

CHEC has information from the Pennsylvania, Department of Environmental Protection (DEP) that the PBT – Josephine Facility treated 15,728,241 gallons of oil and gas wastewater in the 6 month period from July 1, 2010 to December 31, 2010. Using this figure as the amount of effluent wastewater exiting the Josephine outfall and using the mean level of each contaminant found in the effluent over the sampling period of the study, the masses of contaminants with important human and ecological consequences discharged from the PBT,

Josephine Facility into Blacklick Creek in the last 6 months of 2010 are projected to be: barium - 1627 kg (3588 pounds); strontium - 177,712 kg (391,856 pounds; 196 tons); bromides -63,708 kg (140,476 pounds; 70.2 tons); chloride – 7,011,631 kg (15, 460,646 pounds; 7,730 tons); sulfate – 33,382 kg (73,607 pounds; 36.8 tons); 2 butoxyethanol – 3517 kg (7,755 pounds; 3.88 tons); and total dissolved solids – 11,124,733 kg (24,530,036 pounds; 12,265 tons).

Potentially Exposed Populations

Recreationalists are at high risk of being exposed to outfall contaminants through ingestion, inhalation and through dermal exposure. While the pH of outfall water will not cause irreversible eye damage at the maximum observed level of 10 pH units, irritation of the eyes and mucous membranes may occur. The outfall of the Josephine Facility is easily accessible to users of nearby rails-to-trails pathways, and there are indications that anglers frequent the area.[1] Additionally, children wade and swim in the creek during warmer weather, and regional watershed websites indicate that paddlers use the creek for canoeing and kayaking. 2 BE released into Blacklick Creek may be ingested by swimmers in the creek. This pollutant can become airborne and present an inhalation hazard to anglers, swimmers and boaters. It is also taken in to the body via dermal absorption. Anglers catching and eating fish from upstream or downstream of the effluent outfall are at risk for exposure to multiple contaminants that were sampled in this study.

CHEC has developed maps showing numerous private water wells in the immediate vicinity of Blacklick Creek downstream from the effluent discharge. Private well water users are at risk of exposure to contaminants in effluent being released into Blacklick Creek because these private wells may capture water from the creek when the well pump rate is sufficiently high. High pump rates can occur especially during peak usage by residents.

The first identified municipal drinking water intake downstream of this discharge is at Freeport, Pennsylvania on the Allegheny River. Populations served by the Freeport authority and water authorities downstream of Freeport are at potential risk for exposure to contaminants identified in effluent, as well as other contaminants in Marcellus Shale flowback water that were not sampled for in this study.

[1] Blacklick Creek is classified as a 'trout stocking" stream.

Implications of Effluent Discharge from the PBT – Josephine Facility Discharge for Exposures to Other Contaminants Known to be Present in Marcellus Shale Flowback Fluids and a Regional Appreciation of These Results

Of particular environmental public health significance is that Marcellus Shale flowback water contains other contaminants, in addition to those analyzed for in this study, which have health consequences if ingested, inhaled, and/or absorbed through the skin. While we make no statements regarding the presence of other contaminants in this effluent water being discharged into Blacklick Creek, it is imperative that additional testing be conducted immediately by federal and state health and enforcement agencies to determine if other contaminants of public health significance are entering this watershed.

Additionally, oil and gas wastewater and Marcellus shale flowback fluids are being disposed of in "brine treatment" facilities and at Publically Owned Treatment Works (POTW's) throughout the Commonwealth of Pennsylvania and in Ohio, West Virginia, and New York. The ramifications of disposal of large quantities of oil and gas wastewater through ineffectual brine treatment plants and POTW's needs further evaluation throughout the region to determine its impact on stream and river systems and public drinking water supplies, as well as to recreationalists and private well water users.

Recommendations

- The Pennsylvania Brine Treatment – Josephine Facility is discharging up to 60 ppm of 2-BE into Blacklick Creek, which is not listed in its NPDES discharge permit. Other contaminants of human health importance found in effluent but not present on the permit also include bromide, benzene and strontium. Operations at this plant should be halted until all contaminants of human and aquatic health concern in accepted oil and gas fluids are known and it can be determined that the treatment processes used at the plant effectively remove these contaminants from the fluids being treated. The PA DEP should reevaluate the permit given to this operator as it clearly allows for chlorides and total dissolved solids to be discharged at levels exceeding aquatic health criteria.
- All approaches to the effluent discharge area and a reasonable distance downstream (at least 100 meters) from streamside and landside should be posted with warning signs. These signs should discourage any use of and/or contact with stream water.

- An advisory to all anglers should be issued stating that fish taken from this stream, both up and down stream may be contaminated in order to discourage fish take and consumption.
- Studies to determine the levels of all potential Marcellus Shale flowback fluid contaminants in downstream water, sediments and pore water should be undertaken immediately. These should include sampling upstream of the effluent discharge point and at short, intermediate and longer distances downstream from the effluent discharge point. The number of samples (n) of surface water, sediments and pore water upstream and at the various distances downstream should be sufficient so that statistically significant differences of contaminant concentrations can be inferred.
- Residential and other private well water users downstream of the effluent outfall of the PBT-Josephine Facility should be advised that there may be contaminants in their well water and discouraged from using it for drinking, cooking or bathing until such water is tested for continuous safe use. Therefore, it is imperative that well water from wells in close proximity to Blacklick Creek should be tested to assure that contaminants in Marcellus Shale flowback fluids and other oil and gas waste fluids are not present in concentrations that may affect human health.
- Municipal water authorities downstream of this outfall should be notified of the contaminants found in effluent from the PBT- Josephine Facility, of other possible contaminants in Marcellus Shale flowback fluids and oil and gas wastewater, and that there are other treatment facilities and POTW's in the Blacklick, Conemaugh, and Kiskiminetas drainages that accept and discharge oil and gas waste fluids into surface water. Downstream municipal water authorities should test raw unfinished intake water and finished drinking water for these contaminants that have been identified in effluent from the PBT- Josephine Facility, and other contaminants known to be present in Marcellus Shale flowback fluids and oil and gas wastewater.
- All municipal water authorities at reasonable distances downstream of "brine treatment" and POTW's accepting Marcellus Shale flowback fluids and other oil and gas wastewater in the region extending eastward across Ohio, Pennsylvania and West Virginia and New York should be notified of these results. It is important that they initiate sampling of raw, unfinished inflow water and finished drinking water immediately to ensure that their systems are capable of handling all potential contaminants, without breakthrough above specific drinking water MCL's or ATSDR derived MRL's.

- The PA DEP and other state and federal regulatory authorities should immediately review all surface water discharge permits granted to brine treatment facilities and POTW's that accept Marcellus Shale flowback fluids and oil and gas wastewater, to ensure that 2-BE concentrations being discharged are below all applicable standards, guidelines and criteria. This review should be informed by results of this report but should be extended to all known contaminants in flowback and other oil and gas wastewater.

Introduction

Background

Hydraulic fracturing (HF) of shale gas deposits uses considerable masses of chemicals, for a variety of purposes to open and keep open pathways through which natural gas, oil and other production gases and liquids can flow to the wellhead. HF, also known as slick-water fracturing, introduces large volumes of amended water at high pressure into the gas bearing shale where it is in close contact with formation materials that are enriched in organic compounds, heavy metals and other elements, salts and radionuclides. Typically, about 1 million gallons and from 3-5 million gallons of amended water are needed to fracture a vertical well and horizontal well, respectively (Hayes, 2009). Fluids recovered from these wells can represent from 25% to 100% of the injected solution and are called “flowback” or “produced” water depending on the time period of their return.

Flowback and produced water contain high levels of total dissolved solids, chloride, heavy metals and elements as well as enriched levels of organic chemicals, bromide and radionuclides – in addition to the frac chemicals used to make the water slick-water. Levels of shale origin contaminants in flowback water generally increase with increasing time in contact with formation materials.

This oil and gas fluid waste is generally held in temporary open-air impoundment(s) near the well site or occasionally in large sealed containers. Additionally, oil and gas waste fluids accumulate in condenser tanks located on producing well pads, which must be drained regularly. Currently, flowback water is either taken for disposal to a Publically Owned Treatment Plant (POTW, a sewage treatment plant), or a Brine Treatment Facility, both of which discharge effluent directly to surface water sources. The waste fluids may also be recycled for reuse (on-site or off-site at treatment facilities), or injected into Class II underground wells.

The relative volumes of flowback and condensate entering each end-point alternative described above are currently the subject of much heated debate, the unraveling of which is well beyond the scope of this report. For the purposes of this report it is sufficient to note that large volumes of oil and gas wastewater are disposed of in POTW’s and brine treatment facilities that discharge effluent into surface water. The PA Brine Treatment, Josephine Facility received 15,728,242

gallons of Marcellus Shale gas extraction wastewater for treatment and effluent discharge into Blacklick Creek, Indiana County in the last half of 2010. This figure does not include brine from conventional oil wells, which it is also permitted to receive and treat. The Clairton POTW received and disposed of 53,473 gallons of Marcellus Shale wastewater in the last half of 2010, which is ultimately discharged into the Monongahela River.

There is considerable scientific inquiry and even controversy regarding the potential of vertical or horizontal fracturing of shale gas reservoirs to contaminate shallow or confined groundwater aquifers, and thus expose municipal or private well water users to chemicals used in the hydrofracturing process and/or contaminants in the formation materials. However, when Marcellus Shale flowback and produced fluids are disposed of in Publically Owned Treatment Works (POTW's) or inefficient brine treatment facilities discharging into surface water, the fate and transport pathways to expose human and aquatic receptors are well described for most of the contaminants potentially in effluent discharge water and known to be in flowback and other oil and gas wastewater.

Contaminants untreated by the facility and discharged into surface water will move in the water through advective and fickian processes downstream, be deposited and transferred into sediments and pore water, bioaccumulate in aquatic receptors and terrestrial animals that feed on them according to their species specific bioaccumulation factors, be transported to groundwater, and/or be volatilized to air dependent on their Henry's Law constants. Direct and complete human and ecological exposure pathways via ingestion, dermal absorption and inhalation (gill transfer in fish) can be demonstrated for different classes of elements, and compounds in the wastewater, constituting a potential exposure threat to recreationalists, private well water users and municipal drinking water users.

The Pennsylvania Brine Treatment Plant and Effluent Discharges to Blacklick Creek

The Hart Resources managed, Pennsylvania Brine Treatment Inc., Josephine facility is located in Josephine, PA 15750 - a small town in Indiana County, Pennsylvania near Indiana, PA. According to the plant's National Pollutant Discharge Elimination System (NPDES) permit, the facility can release up to 0.155 million gallons per day (mgd) of effluent to Blacklick Creek, a tributary of the Conemaugh River, which flows into the Kiskikiminetas River and ultimately the

Allegheny River near Freeport, PA (see Figure 1, Conemaugh River Basin and Locations of Facilities Accepting Oil and Gas Waste and Wastewater). Hart Resources also manages two other wastewater treatment facilities; one in the immediate area called the Hart Resources Treatment Facility (discharges to McKee Run) and the other in Franklin, PA, called PA Brine Treatment, Franklin. Marketing literature for these plants states that:

> 'Pennsylvania Brine Treatment, Inc. is permitted to accept all fluids generated through the ordinary course of oil and/or gas well drilling and producing operations,'

and that

> 'Pennsylvania Brine Treatment, Inc. is permitted to accept only oil and gas industrial wastewater.'

The relative volumes of unconventional drilling waste fluids from Marcellus Shale gas extraction operations and conventional oil waste fluids accepted by the Josephine Facility are not known.

The Josephine facility's National Pollutant Discharge Elimination System (NPDES) permit was last renewed on July 1, 2008, and does not expire until June 30, 2013. The facility is permitted for a single outfall, located at (40.480556°N, 79.169056°W). Effluent limits for this facility are presented in Table 1, Discharge parameters for the PBT, Josephine facility, established in the NPDES permit. In addition to the pollutants listed in Table 1, the facility is required to notify the PA DEP if they discharge any of the following on a routine or frequent basis: 100 µg/L of any toxic pollutant; 200 µg/L for acrolein and acrylonitrile; 500 µg/L for 2,4-dinitrophenol and 2-methyl-4,6-dinitrophenol; 1 mg/L antimony; five times the maximum concentration set for any of the limited pollutants (Table 1), or any other notification level established by the PA DEP. The facility is also required to notify the PA DEP if they release any of the following on a nonroutine infrequent basis; 500 µg/L of any toxic pollutant; 100 mg/L antimony; ten times the maximum concentration set for any of the limited pollutants (Table 1), or any other notification level established by the PA DEP. A PBT, Josephine Discharge Monitoring Report found at the end of this report as Appendix A, shows daily discharge into Blacklick Creek from the plant, self-reported monitoring results of

effluent discharge parameters, and volumes of wastewater received from each customer-for the period from December 1-31, 2010.

At the Josephine facility, wastewater is hauled in with 5,000-gallon residual waste tanker trucks, and the influent is treated continuously. After removing debris in an open spillway, treatment begins in a settling tank. Sodium sulfate and polymer are then added to the oil and gas wastewater to precipitate barium. Fine lamellae screens then filter and clarify the wastewater. A silicone defoamer is added prior to discharge. The solid waste is dried with a mechanical press and is trucked to residual waste landfills. Figure 2, Pennsylvania Brine Treatment, Josephine Facility Offloading, shows residual waste tanker trucks offloading waste fluids into the plant for continuous treatment.

Table 1. Discharge Parameters for the PBT, Josephine facility, established in the NPDES permit, effective July 1, 2008 to June 30, 2013

Effluent Limitations				Monitoring Requirements	
Pollutant	Average - Monthly	Maximum - Daily	Maximum - Instantaneous	Minimum Sampling Frequency	Sample Type
Flow		0.155 mgd		Daily	Measured
Iron (total)	3.5 mg/L		7 mg/L	2/Month	8 hr composite
Oil and Grease	15 mg/L		30 mg/L	2/Month	Grab
Total Suspended Solids	30 mg/L		60 mg/L	2/Month	8 hr composite
Acidity		Monitor Only		2/Month	8 hr composite
Alkalinity		Greater than Acidity		2/Month	8 hr composite
pH		6 to 9.5 s.u.		2/Month	grab
Barium	114 mg/L	228 mg/L		2/Month	8 hr composite
Chlorides		Monitor Only		2/Month	8 hr composite
Total Dissolved Solids		Monitor Only		2/Month	8 hr composite
Osmotic Pressure		Monitor Only		2/Month	8 hr composite

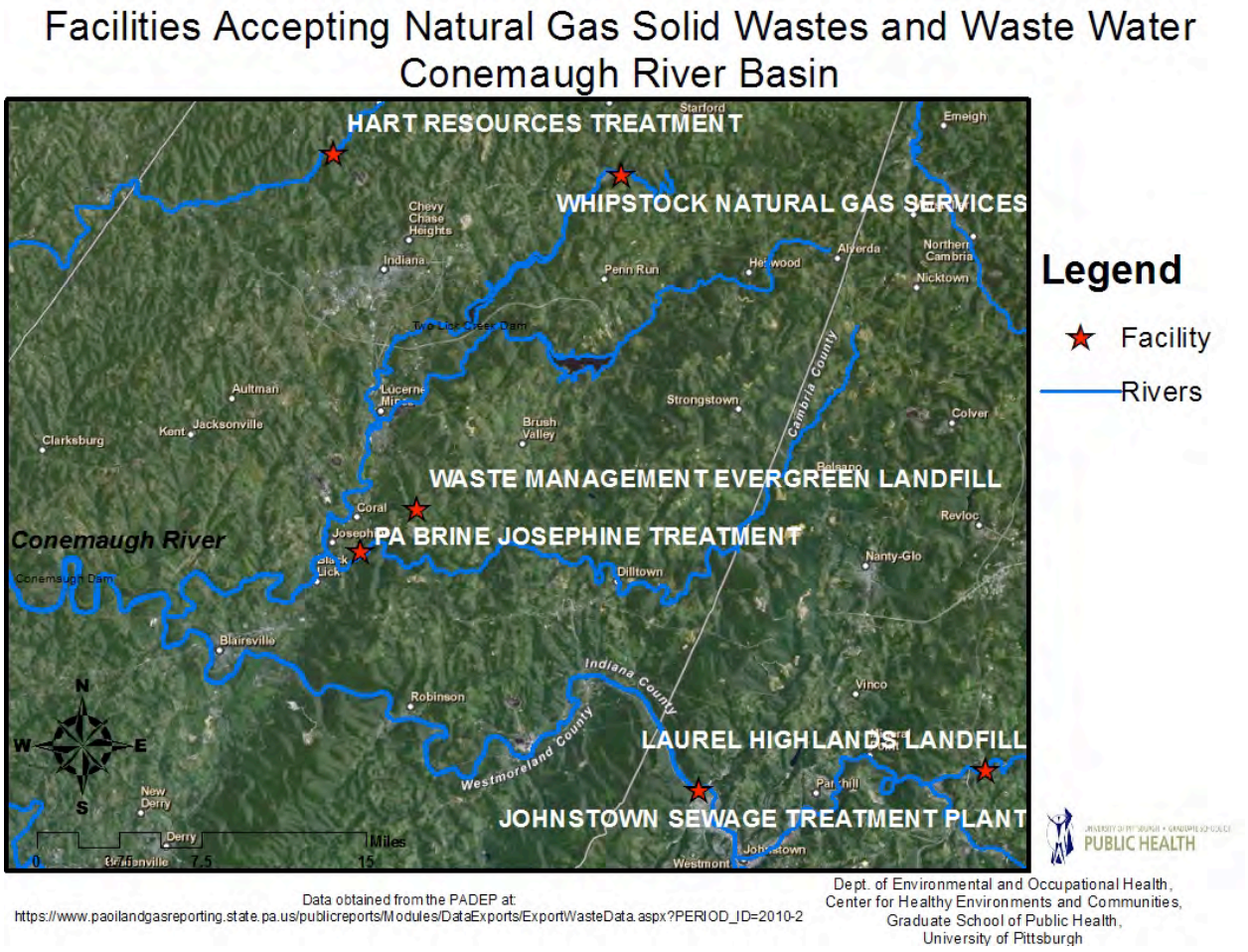

Figure 1. Conemaugh River Basin and Locations of Facilities Accepting Oil and Gas Waste and Wastewater

Figure 2. Pennsylvania Brine Treatment, Josephine Facility Offloading [Picture taken by Kyle Ferrar, December 1, 2010, at location (40.826°N, 79.172°W)]

After treatment at the PA Brine, Josephine Facility the resulting waste effluent is piped for discharge into Blacklick Creek. Figure 3, Effluent Outfall on Blacklick Creek is a picture of waste effluent being discharged from the outfall pipe. Figure 4, Entry of Waste Effluent into Blacklick Creek shows the effluent entering Blacklick Creek; one can see the foam plume. The effluent smells similar to a spill of condensate tank fluids the authors sampled at a vertical Marcellus well that was hydrofractured and was producing wet gas.

Figure 3. Effluent Outfall on Blacklick Creek [Picture taken by Kyle Ferrar, December 10, 2010, at location (40.481°N, 79.169°W)]

Figure 4. Entry of Waste Effluent into Blacklick Creek [Picture taken by Kyle Ferrar, December 10, 2010, at location (40.481°N, 79.169°W)]

Methodology and Protocols

Sampling of effluent, from the Hart Resources - PA Brine Josephine facility was conducted on December 10th and 11th, 2010. This facility discharges treated oil and gas wastewater/brine/Marcellus Shale flowback water directly into Blacklick Creek, Indiana County. Figure 5, Location of Discharge Pipe on Blacklick Creek Relative to the PA Brine Treatment, Josephine Facility, shows the relative locations of the plant, and the discharge pipe where effluent was collected (Please note a characteristic spreading plume in Blacklick Creek, immediately downstream of the discharge point). The imagery in Figure 5 was updated on May 28, 2008. The location of the discharge into Blacklick Creek was recorded using a Garmin 60 csx GPS device.

Kyle Ferrar, MPH and Andrew Michanowicz, MPH, CPH conducted sampling to characterize a full 24-hour period of discharge. Eight individual samples, taken at 3-hour intervals, were collected from the effluent discharge pipe. Sampling began at 11:00 (11:00 AM) December 10, 2010, and the last sampling event occurred 8:00 (8:00 AM) December 11, 2010. Three sample vessels were filled during each sampling time. The first sample was taken in 1L nalgene vessels for analysis of inorganic chemicals. The second and third samples were both taken in 50 mL glass vials with Teflon caps, for analysis of organic chemicals. Samples were appropriately identified on-site and given sample numbers, and chain of custody forms were developed and the samples were taken to the R.J. Lee Group, Monroeville PA for subsequent analysis. Sampling data and information was initiated on-site, on paper and subsequently transferred to an electronic database. The eight effluent samples were analyzed for the following contaminants/water quality variables: aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), calcium (Ca), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), strontium (Sr), zinc (Zn), bromides (Br), chloride (Cl), sulfate (SO4), total dissolved solids (TDS), benzene, ethylbenzene, toluene, xylenes, 2-butoxyethanol (2-BE), and pH units. Analyses were conducted according to the following EPA approved methods: EPA 200.7-PA (Al, Ba, Ca, Fe, Mg, Mn, Sr, Zn), EPA 200.8-PA (As, Cd, Cu, Pb, Ni), EPA 300.0-PA (Bromide, Chloride, Sulfate), and SM2540C-PA (TDS). Minimum detection limits (MDL's) for each method, for each analyte are presented in Table 2, Descriptive Statistics, Analyte Concentrations in Effluent Discharge from the PA Brine Treatment Plant, Josephine Facility, which is contained in the results section of this report.

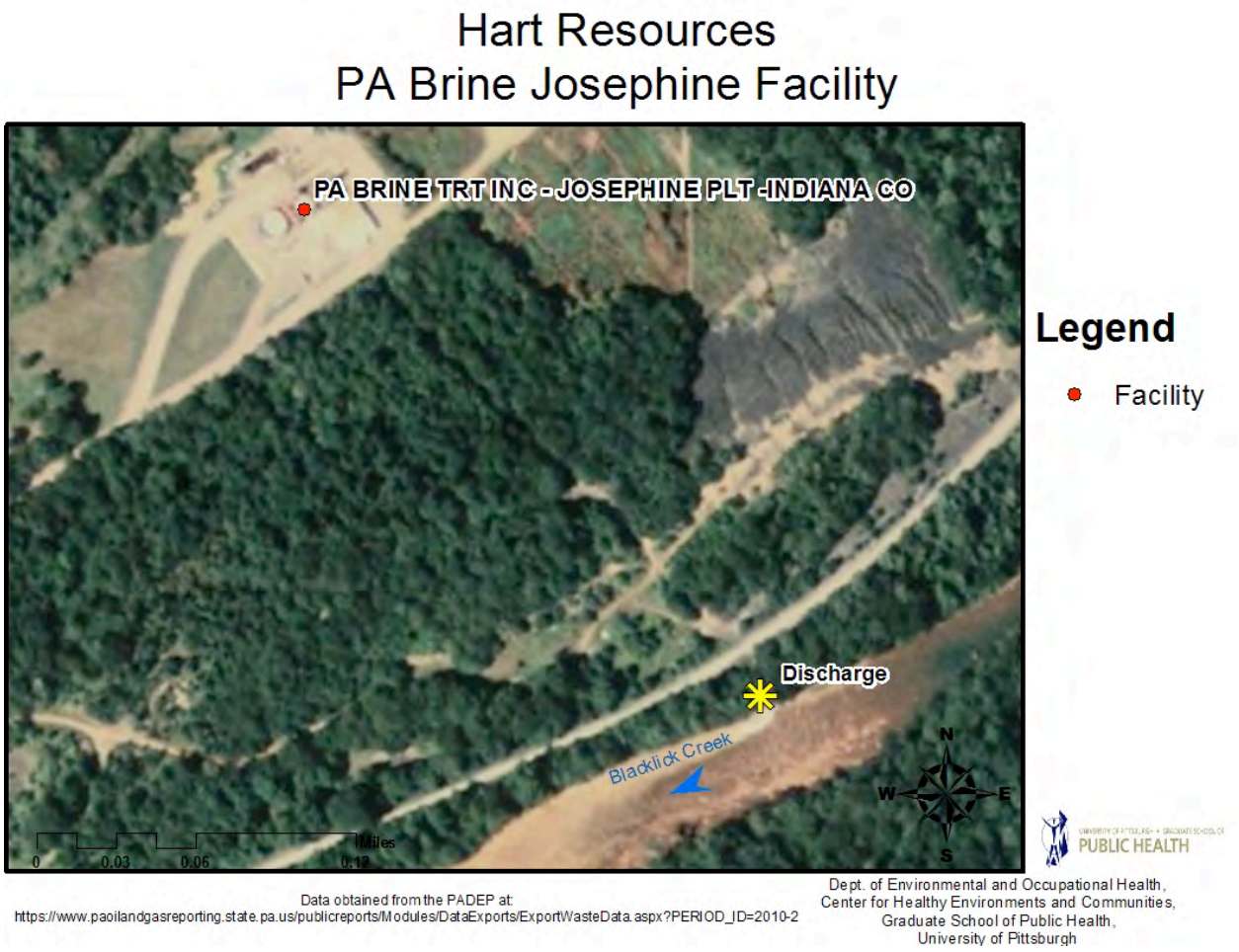

Figure 5. Location of Discharge Pipe on Blacklick Creek Relative to the PA Brine Treatment, Josephine Facility

Results

Table 2, Descriptive Statistics, Analyte Concentrations in Effluent Discharge from the PA Brine Treatment Plant, Josephine Facility, presents the mean, standard error, median, mode, standard deviation, variance, range of concentration, and the minimum and maximum concentrations of each analyzed element, chemical, and water quality variable. Time series plots, in ppm or mg/L, were produced for concentrations of Ba, Ca, Mg, Sr, Br, Cl, SO4, TDS, benzene, ethylbenzene, toluene, xylenes, 2-BE, and pH in the effluent discharge for the entire sampling frame, and are presented as Figures 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, and 19, respectively.

The Gas Technology Institute report states that in Marcellus shale flowback water "cations are dominated by sodium and calcium, and the main anion is chloride" (Hayes, 2009). In the effluent of the PA Brine Josehpine facility these three inorganics were the most concentrated analytes in the descending sequence, chloride (mean, 117,625 ppm), sodium (mean, 39,713 ppm), and then calcium (mean, 16,300 ppm). These results seem to indicate that the predominant cations and anion in Marcellus flowback water are the predominant cations and anion in the effluent leaving the PA Brine, Josephine Facility and entering Blacklick Creek.

Contaminants of environmental public health importance that were detected in all samples taken over the 24 hour period are; Ba (mean, 27.3 ppm); Sr (mean, 2981.2 ppm); Br (mean, 1068.8 ppm); benzene (mean, 0.012 ppm); ethylbenzene (mean, 0.002 ppm); toluene (mean, 0.025 ppm); xylenes (mean, 0.028 ppm) and 2-butoxyethanol (mean, 59.00 ppm; maximum, 66.00 ppm). 2-Butoxyethanol (2-BE) is used in the oil and gas extraction/drilling process as an anti-foaming agent, surfactant, and corrosion inhibitor. Its high concentration in effluent water emenating from the plant could indicate that flowback water treated at the plant contains high levels of 2-BE, which was added to make slick-water for fracturing and/or was added during the plant's treatment process to reduce foam. CHEC is requesting Material Safety Data Sheets from the plant operators to help determine its orign in the effluent water. 2-BE is not permitted to be released at this facility. The total dissolved solids level was particularly high in all samples, TDS (mean, 166,625 ppm; maximum, 190,000 ppm).

Other water quality variables of interest detected in all samples were Fe (mean, 0.13 ppm), Mg (mean, 1247.5 ppm), Mn (mean, 0.1 ppm), and sulfate (mean, 560 ppm). Sulfate in effluent from the PA Brine Josephine Plant is attributable to the

sodium sulfate added to the wastewater during the facilities treatment process and/or to sulfate in the brine fluids themselves. Al, Zn, Cd, Cu, Pb, and Ni levels in the effluent were all below the detection limit of the analytical method employed. The pH of effluent water had a mean of 9.58 units and reached a maximum of 9.6 units.

Table 2. Descriptive Statistics, Analyte Concentrations in Effluent Discharge from the PA Brine Treatment Plant, Josephine Facility

Descriptive Statistics for the PA Brine Josephine Facility Sampled 12/10/10

Analyte	Aluminum (mg/L)	Barium (mg/L)	Calcium (mg/L)	Iron (mg/L)	Magnesium (mg/L)	Manganese (mg/L)	Strontium (mg/L)
Mean	ND	27.30	16300.00	.13	1247.50	.08	2981.25
Means Std. Error	ND	2.461	204.416	.029	9.402	.015	29.243
Median	ND	26.60	16300.00	.11	1240.00	.07	2970.00
Mode	ND	20	16400	NA	1240	NA	2970
Std. Deviation	ND	6.962	578.174	.083	26.592	.041	82.711
Variance	ND	48.471	334285.700	.007	707.143	.002	6841.071
N	8	8	8	8	8	8	8
Range	ND	17	1900	.231	90	.119	240
Minimum	ND	20	15600	.002	1210	.026	2880
Maximum	ND	37	17500	.233	1300	.145	3120
MDL	0.02	0.002	1	0.004	2	0.001	0.03

Descriptive Statistics for the PA Brine Josephine Facility Sampled 12/10/10

Analyte	Zinc (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Copper (mg/L)	Lead (mg/L)	Nickel (mg/L)	Bromide (mg/L)
Mean	ND	ND	ND	ND	ND	ND	1068.75
Means Std. Error	ND	ND	ND	ND	ND	ND	9.531
Median	ND	ND	ND	ND	ND	ND	1080.00
Mode	ND	ND	ND	ND	ND	ND	1080
Std. Deviation	ND	ND	ND	ND	ND	ND	26.959
Variance	ND	ND	ND	ND	ND	ND	726.786
N	8	8	8	8	8	8	8
Range	ND	ND	ND	ND	ND	ND	80
Minimum	ND	ND	ND	ND	ND	ND	1020
Maximum	ND	ND	ND	ND	ND	ND	1100
MDL	0.005	0.0002	0.00002	0.0004	0.00003	0.0004	0.016

*Table continued on next page.

Descriptive Statistics for the PA Brine Josephine Facility Sampled 12/10/10

Analyte	Chloride (mg/L)	Sulfate (mg/L)	Total Dissolved Solids (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Benzene (mg/L)
Mean	117625.00	560.00	186625.00	1336.25	39712.50	.0121
Means Std. Error	1348.776	8.371	1084.592	15.462	258.731	.0001
Median	117000	559	187000	1325	39550	.012
Mode	117000	585	186000	1320	39100	.012
Std. Deviation	3814.914	23.676	3067.689	43.732	731.803	.0004
Variance	1.455E+07	560.571	9.411E+06	1912.500	535536	1.250E-07
N	8	8	8	8	8	8
Range	14000	64	10000	140	2000	.001
Minimum	111000	521	180000	1280	38900	.012
Maximum	125000	585	190000	1420	40900	.013
MDL	1.5	8.7	NA	NA	NA	0.002

Descriptive Statistics for the PA Brine Josephine Facility Sampled 12/10/10

Analyte	Ethylbenzene (mg/L)	Toluene (mg/L)	Xylenes (mg/L)	2-Butoxyethanol (mg/L)	pH (pH Units)
Mean	.0018	.0254	.0283	59.00	9.58
Means Std. Error	.00004	.0005	.0012	1.732	.006
Median	.0018	.025	.027	59.50	9.58
Mode	.0018	.025	.027	49	10
Std. Deviation	.0001	.002	.0035	4.899	.017
Variance	1.125E-08	4.0E-06	1.0E-05	24.000	.0003
N	8	8	8	8	8
Range	.0003	.005	.011	17	0
Minimum	.0018	.024	.025	49	9.55
Maximum	.0021	.029	.036	66	9.6
MDL	0.002	0.002	0.002	0.63	NA

*ND=Not Detected NA=Not Available

Center for Healthy Environments and Communities, Department of Environmental and Occupational Health, Graduate School of Public Health, University of Pittsburgh

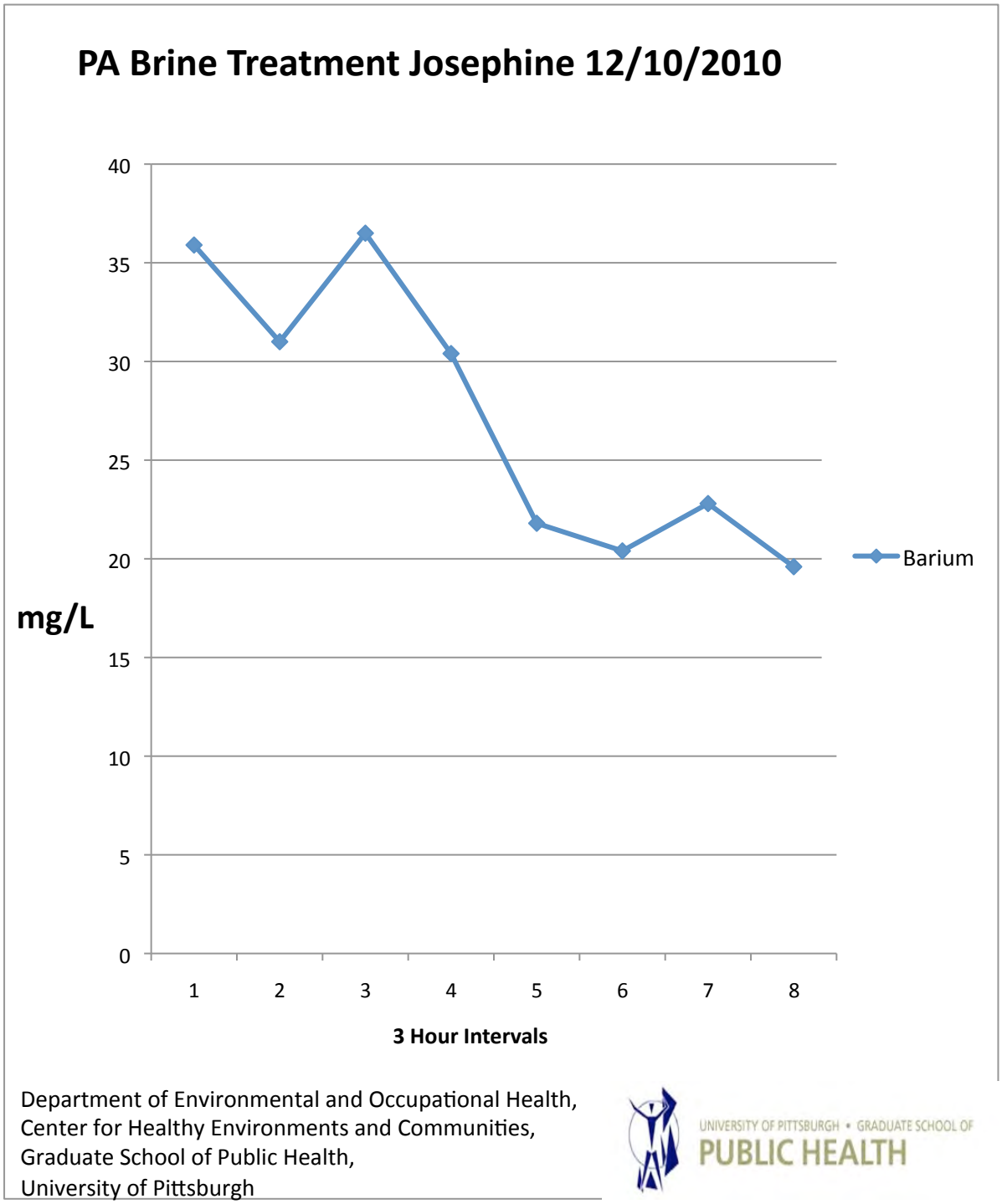

Figure 6. Time-plot of Barium Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 1100 (11:00 AM)].

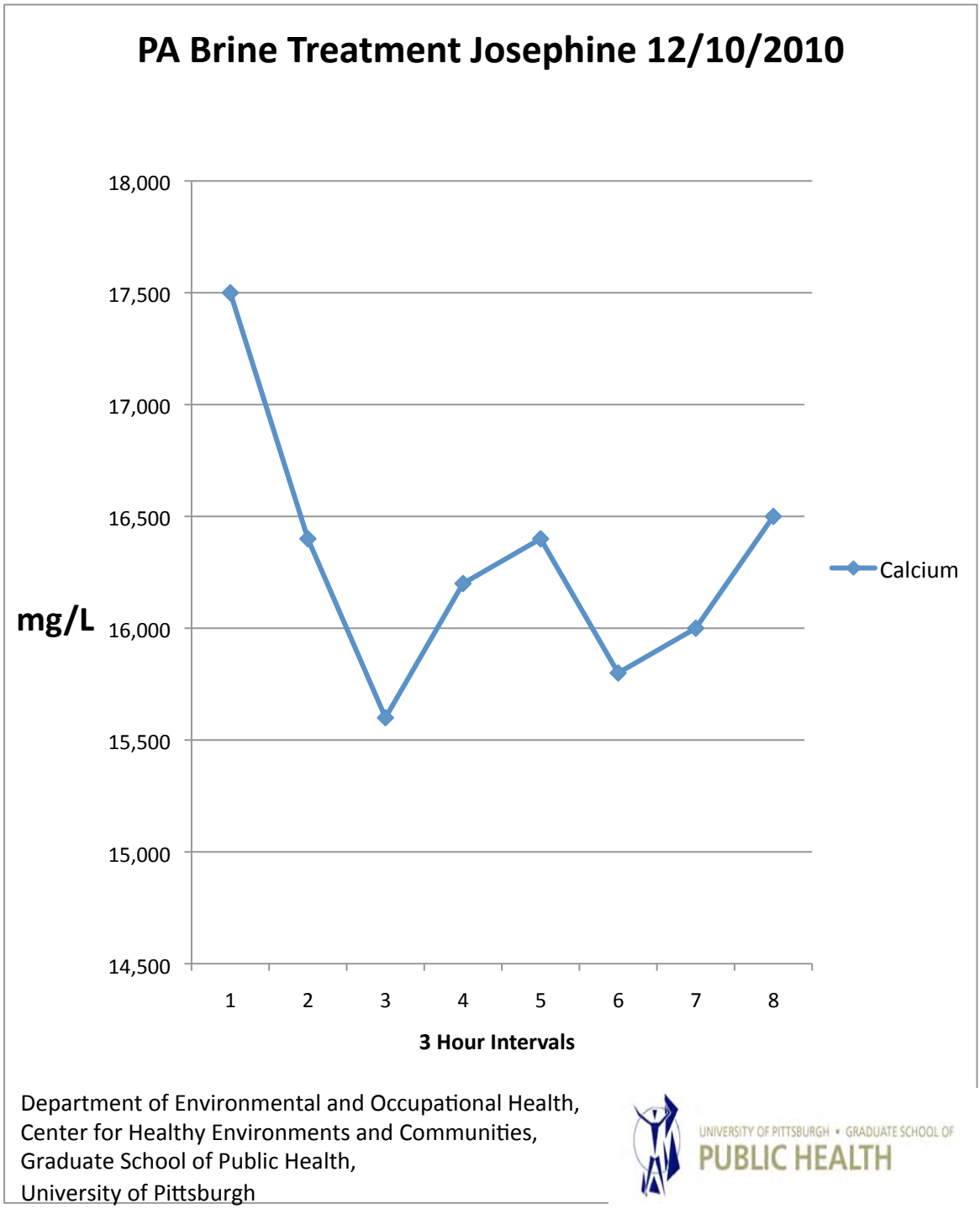

Figure 7. Time-plot of Calcium Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 1100 (11:00 AM)].

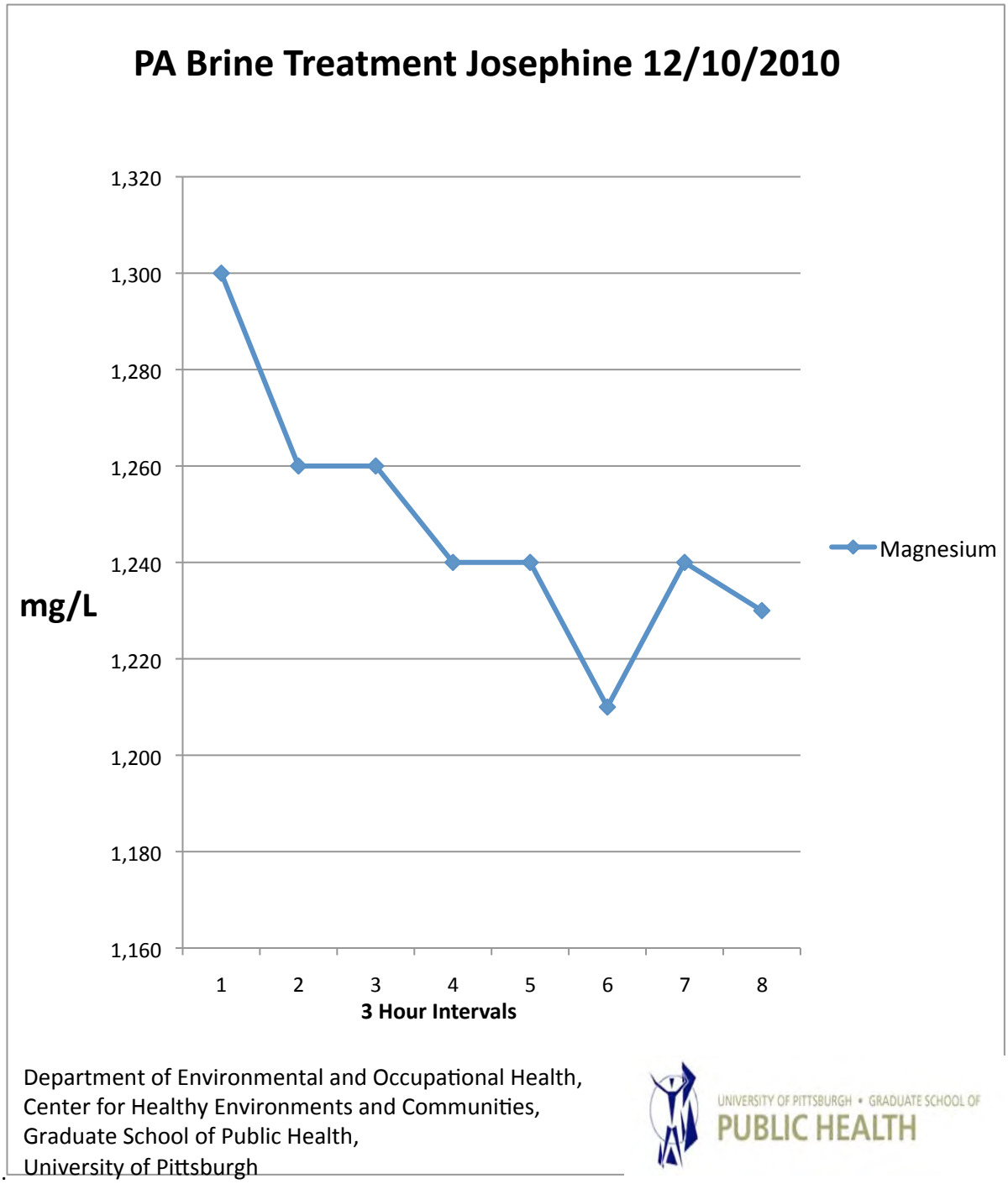

Figure 8. Time-plot of Magnesium Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 1100 (11:00 AM)].

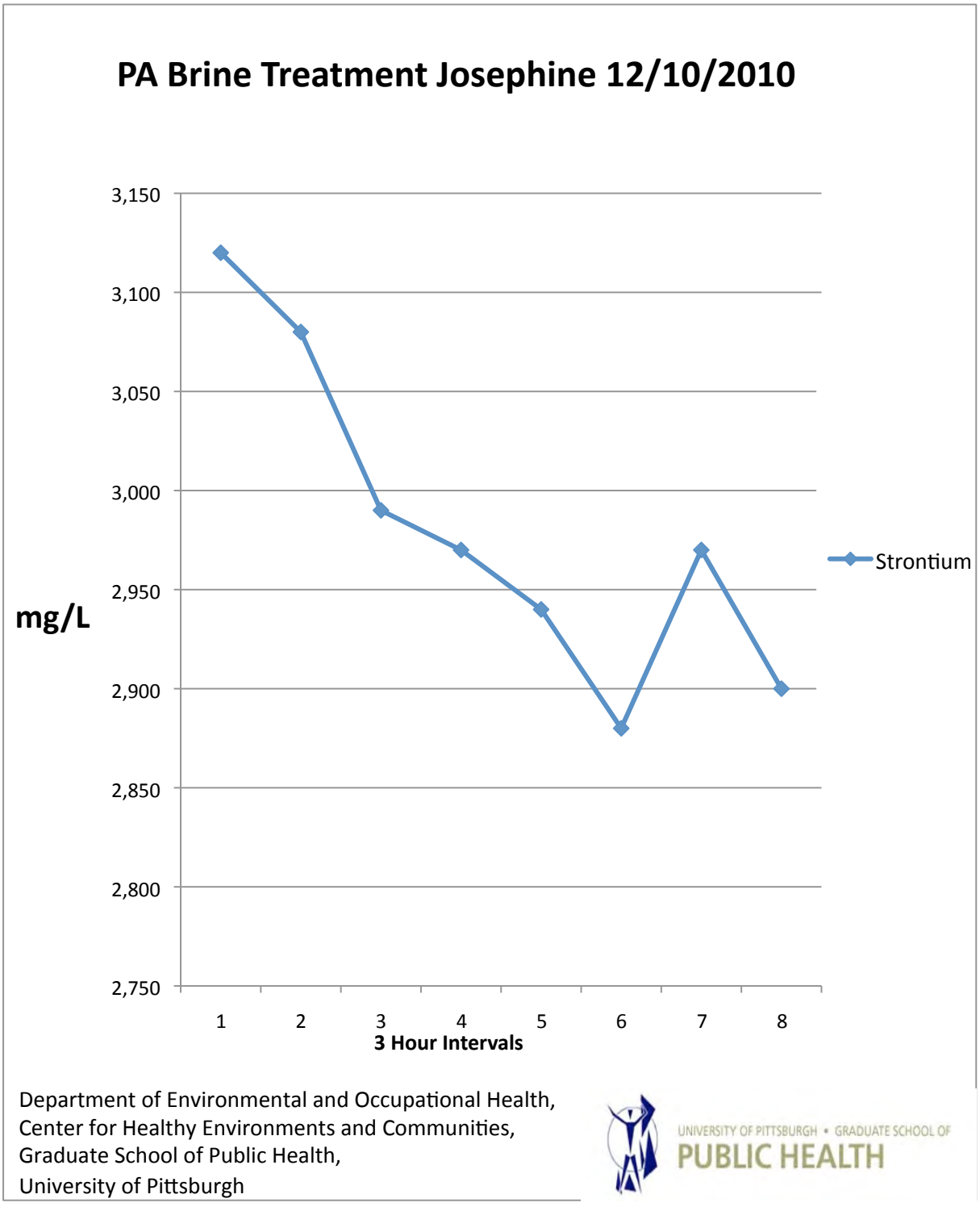

Figure 9. Time-plot of Strontium Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 11:00 (11:00 AM)].

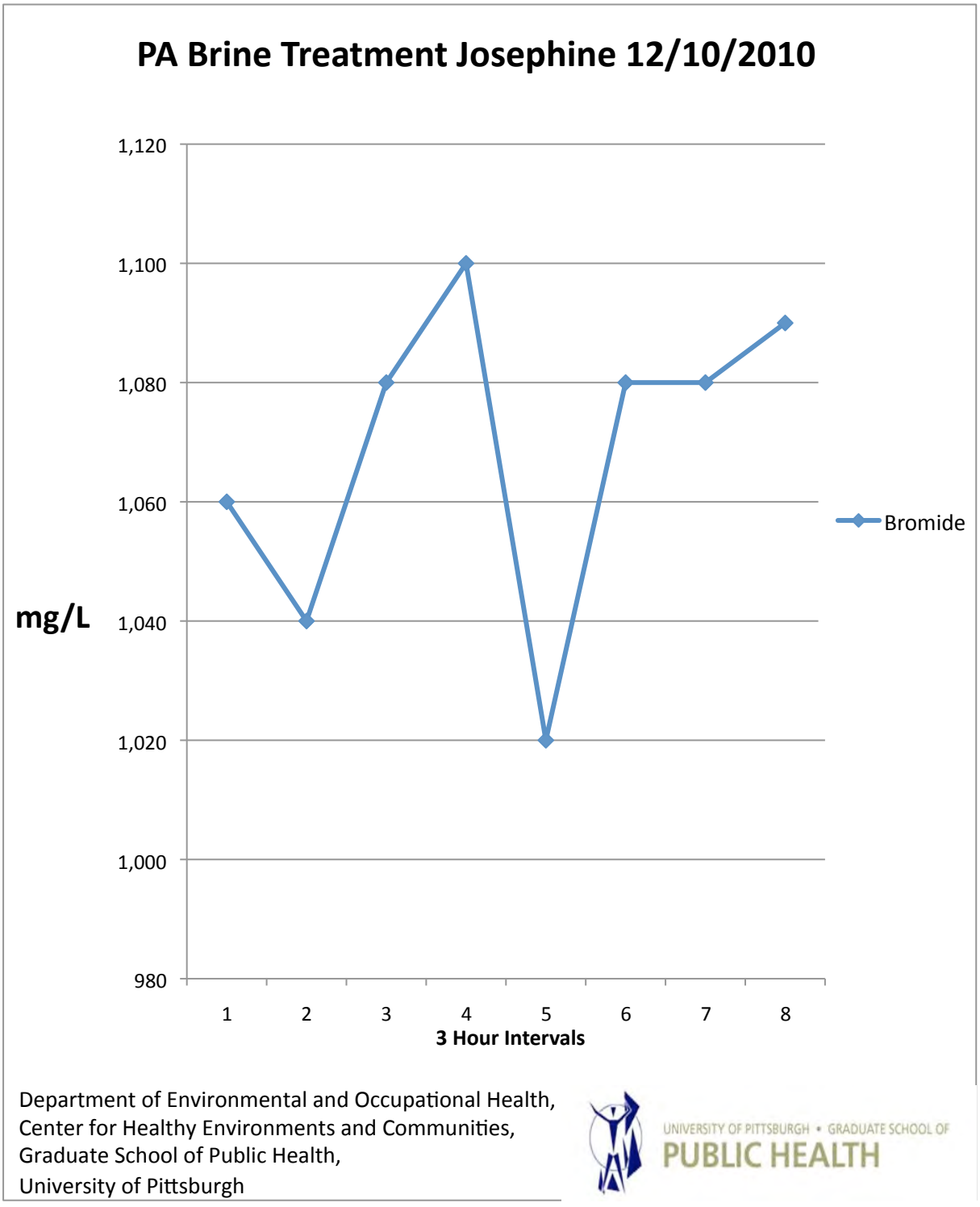

Figure 10. Time-plot of Bromide Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 11:00 (11:00 AM)].

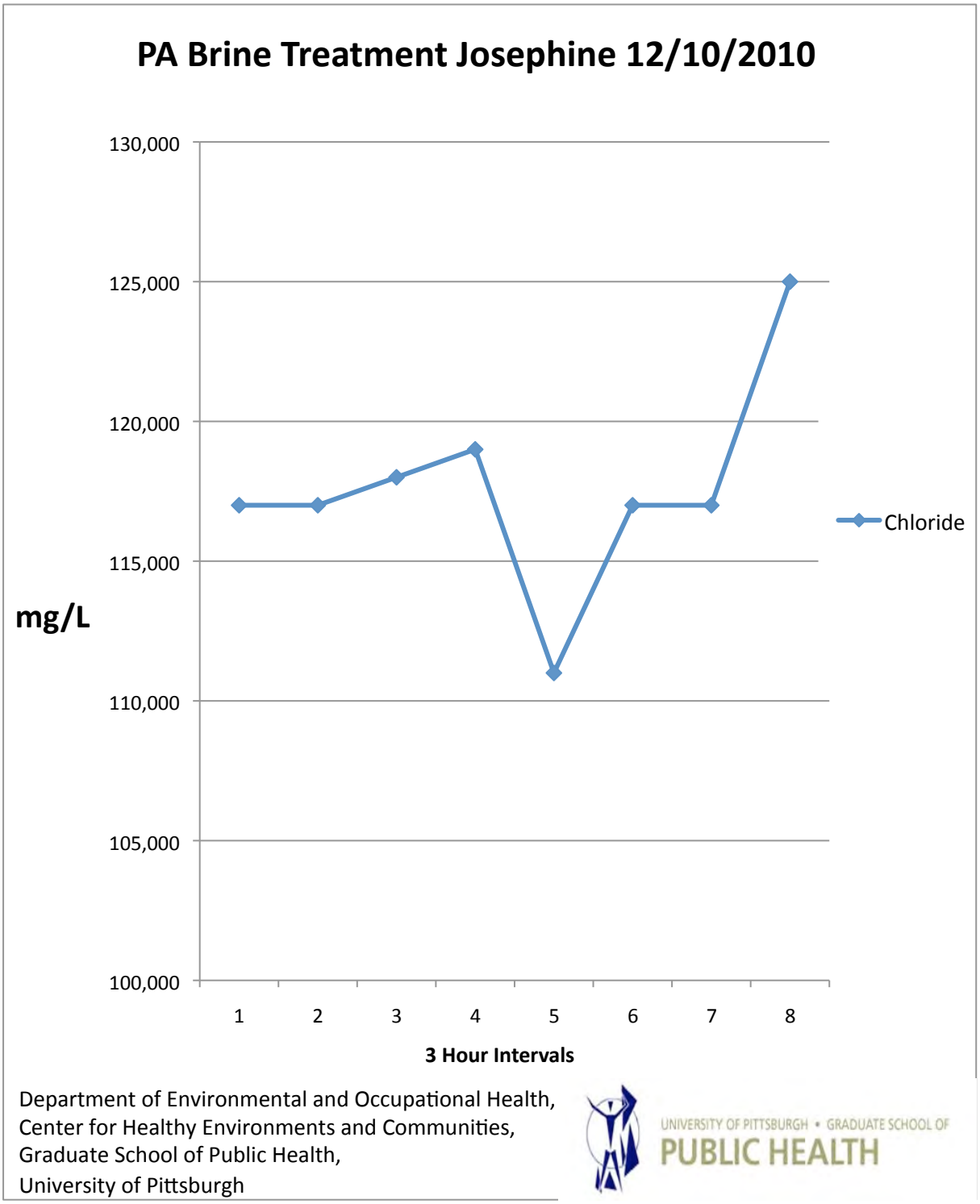

Figure 11. Time-plot of Chloride Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 11:00 (11:00 AM)].

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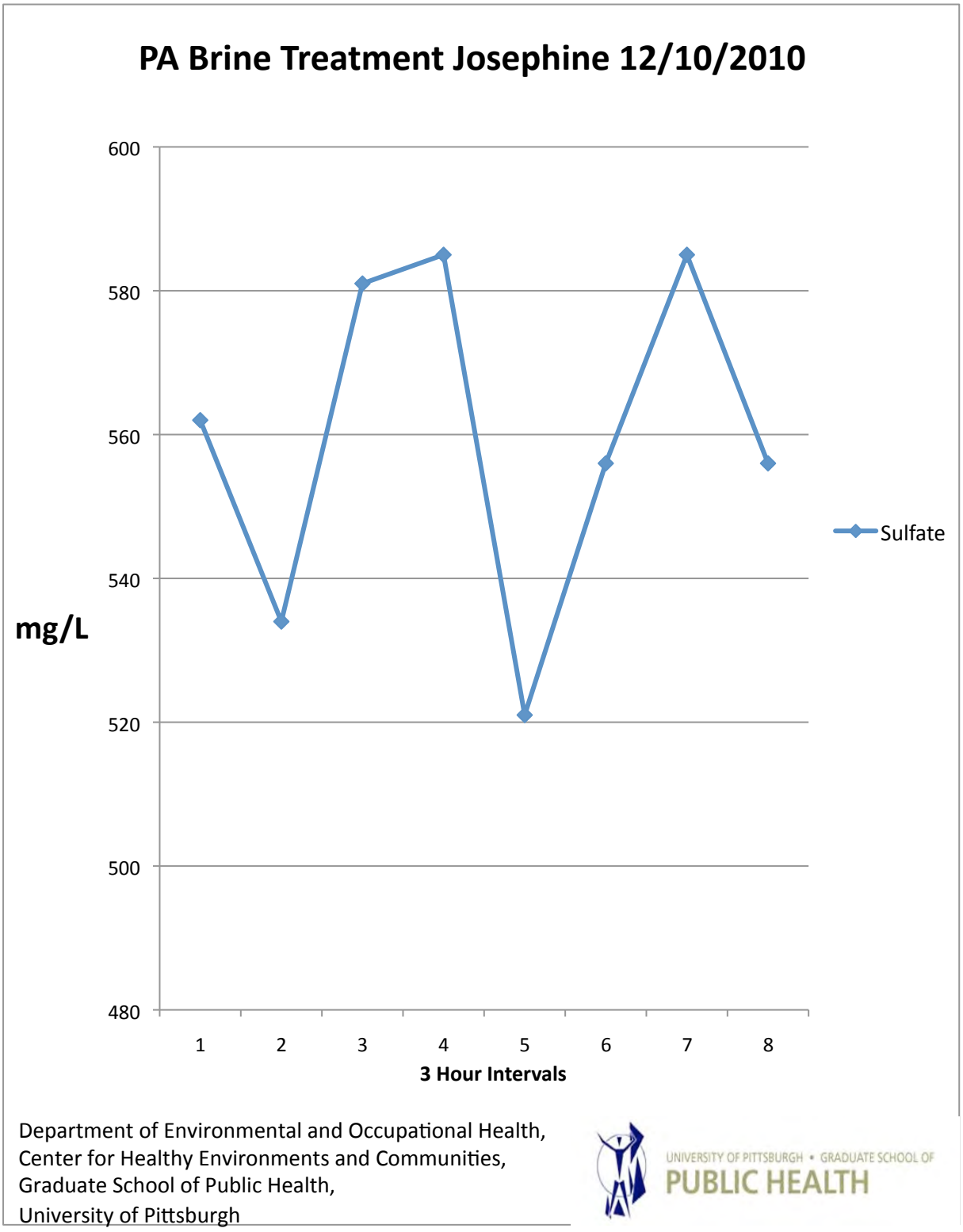

Figure 12. Time-plot of Sulfate Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 11:00 (11:00 AM)]

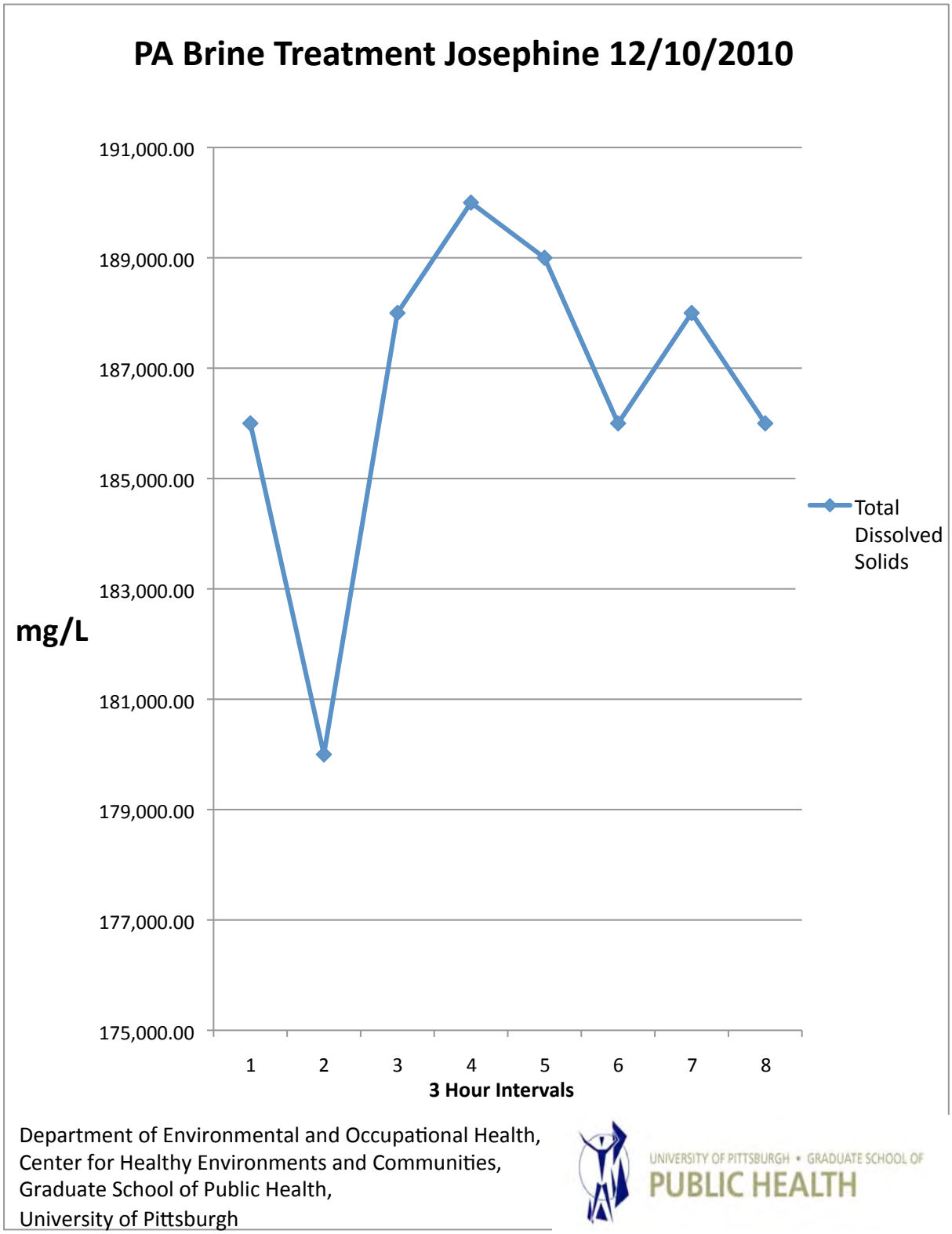

Figure 13. Time-plot of TDS Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 11:00 (11:00 AM)]

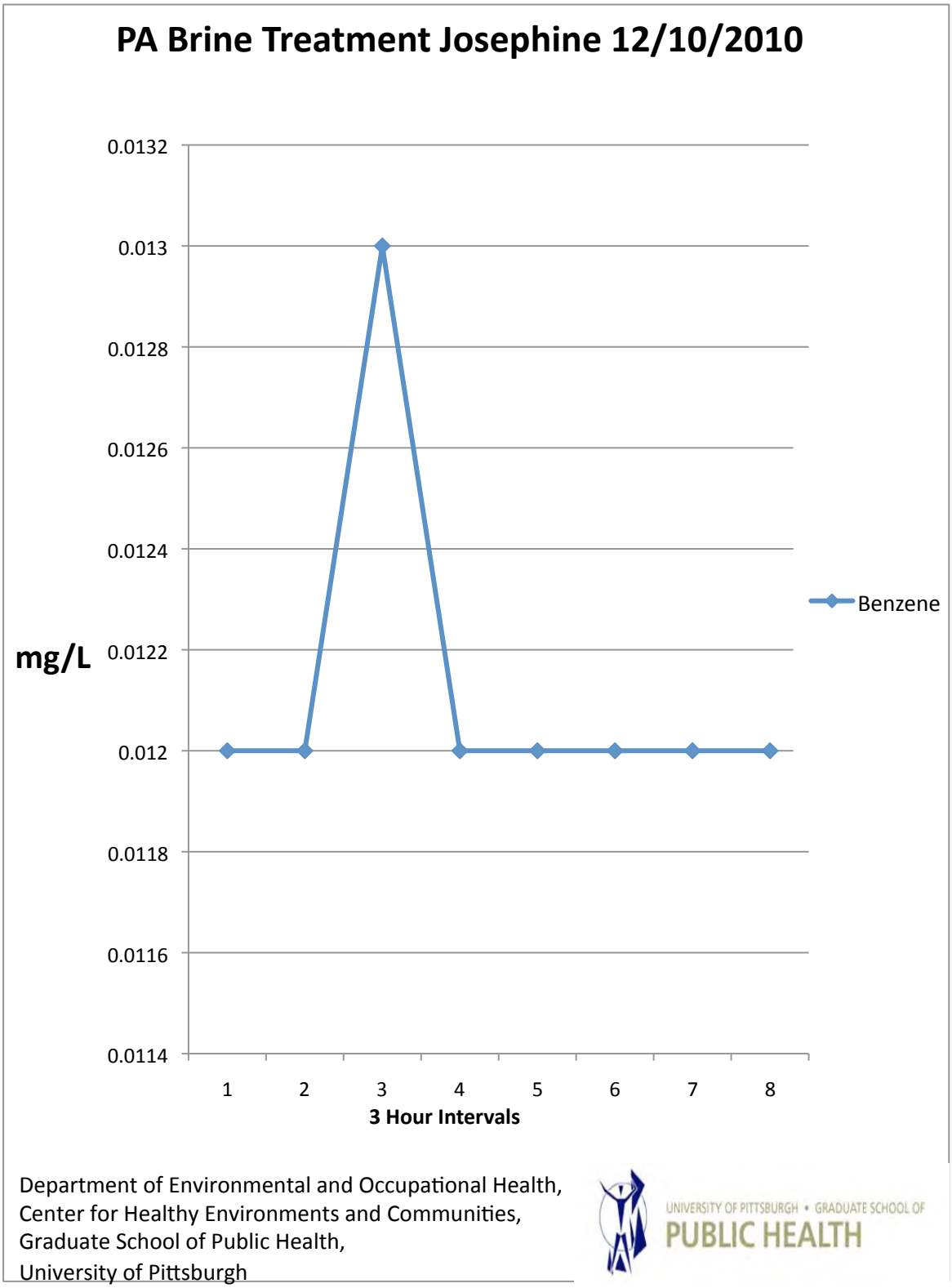

Figure 14. Time-plot of Benzene Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 11:00 (11:00 AM)]

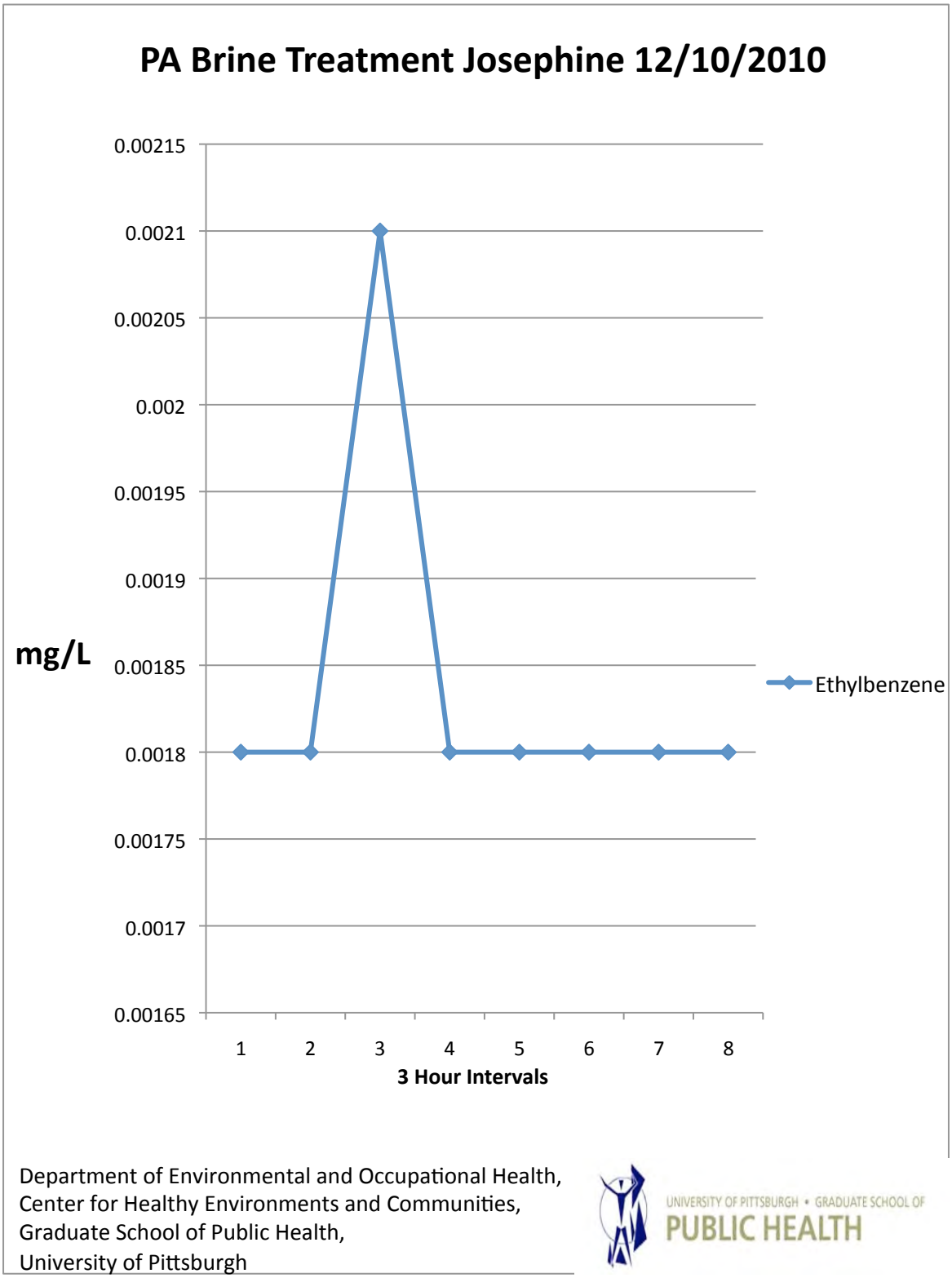

Figure 15. Time-plot of Ethylbenzene Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 11:00 (11:00 AM)]

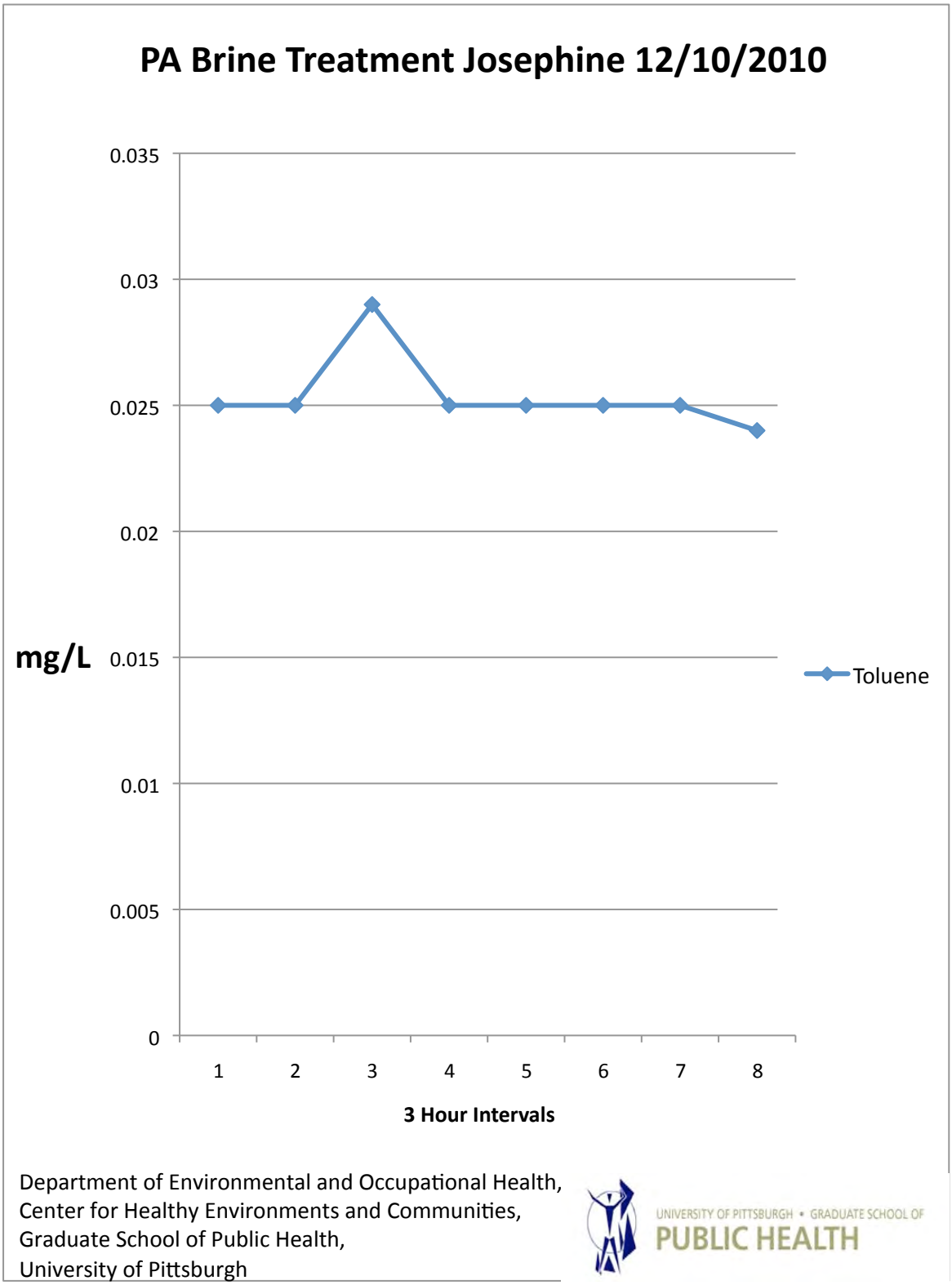

Figure 16. Time-plot of Toluene Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 11:00 (11:00 AM)]

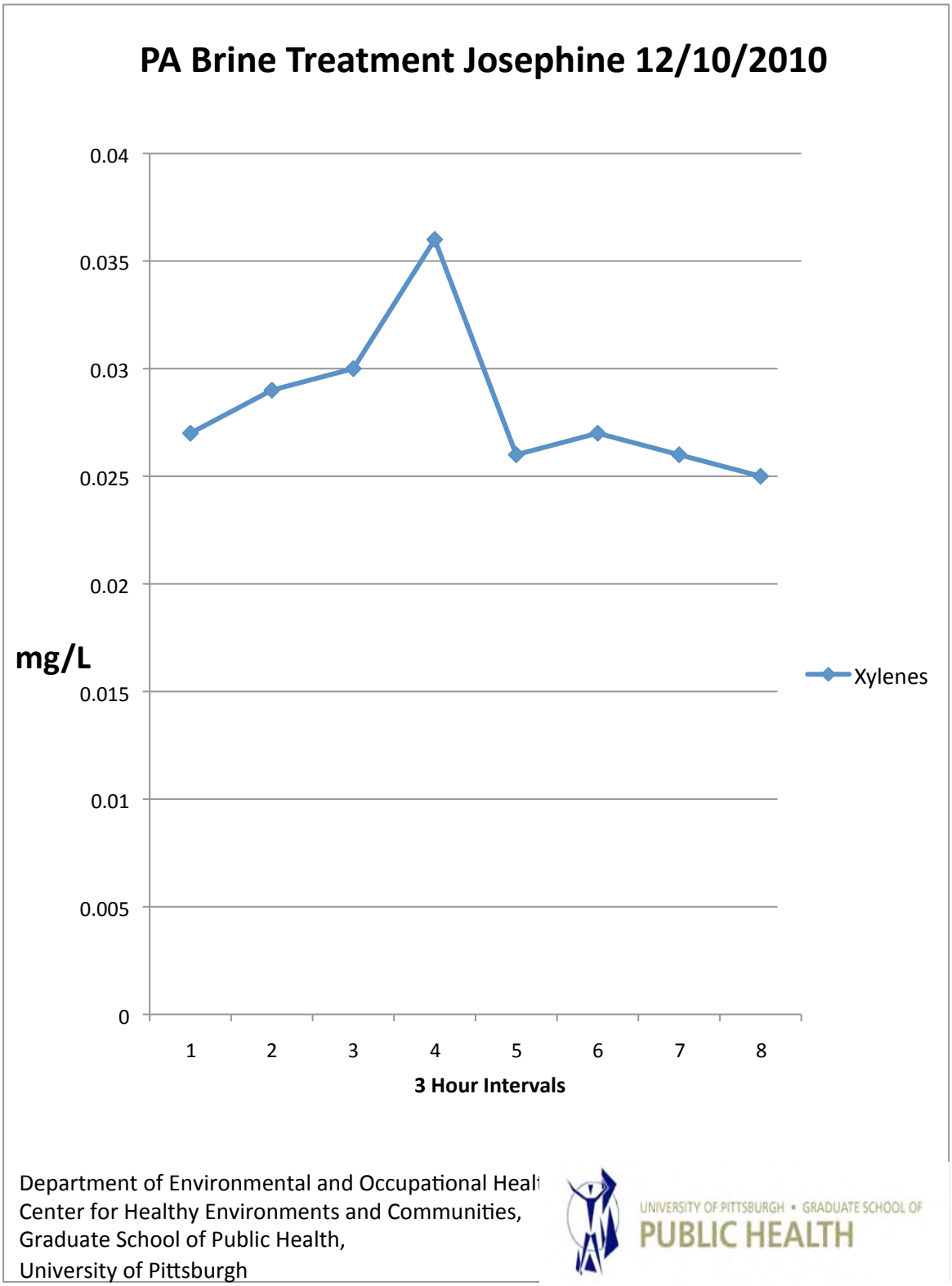

Figure 17. Time-plot of Xylenes Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 11:00 (11:00 AM)]

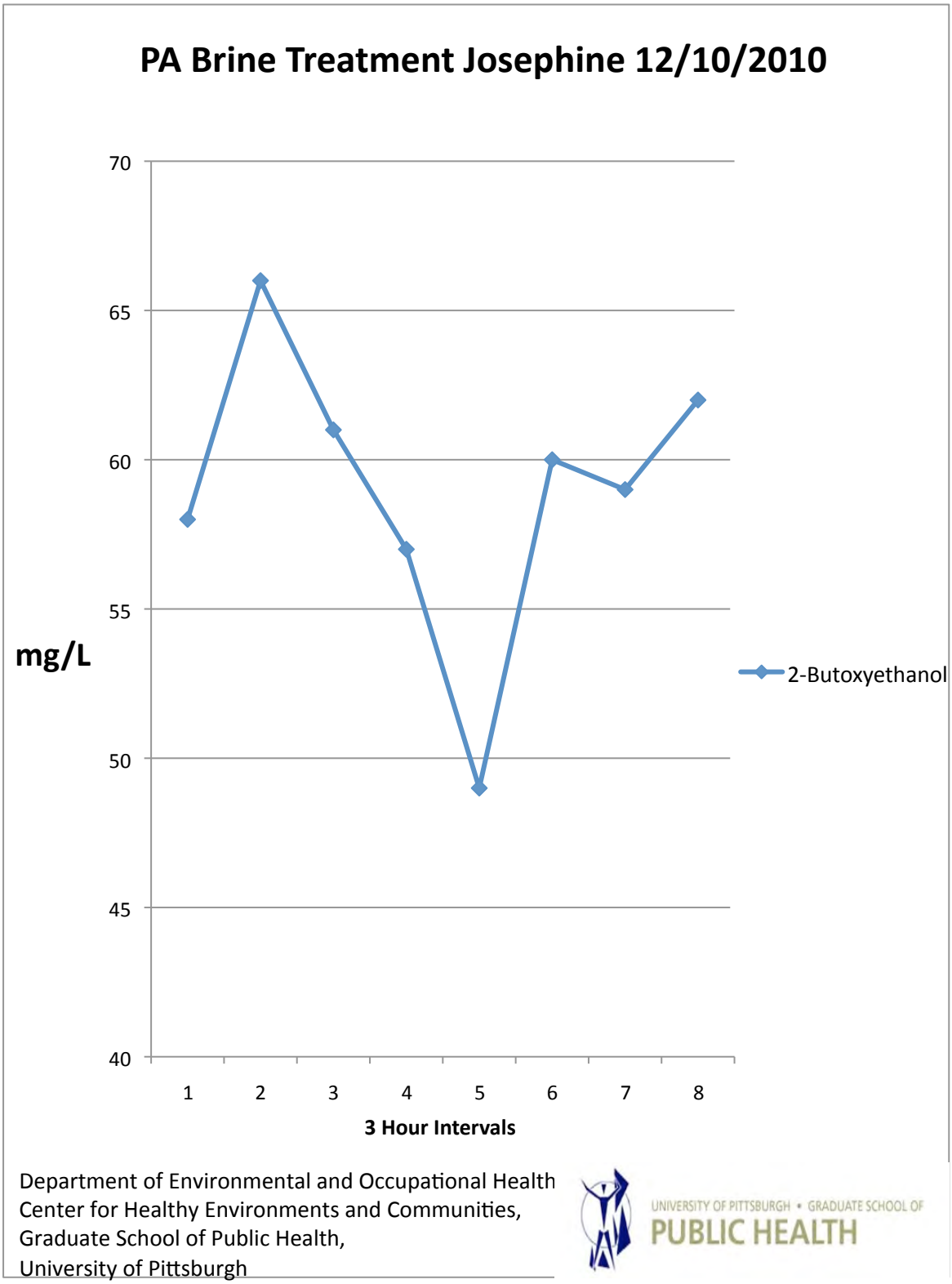

Figure 18. Time-plot of 2-Butoxyethanol (2-BE) Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 11:00 (11:00 AM)]

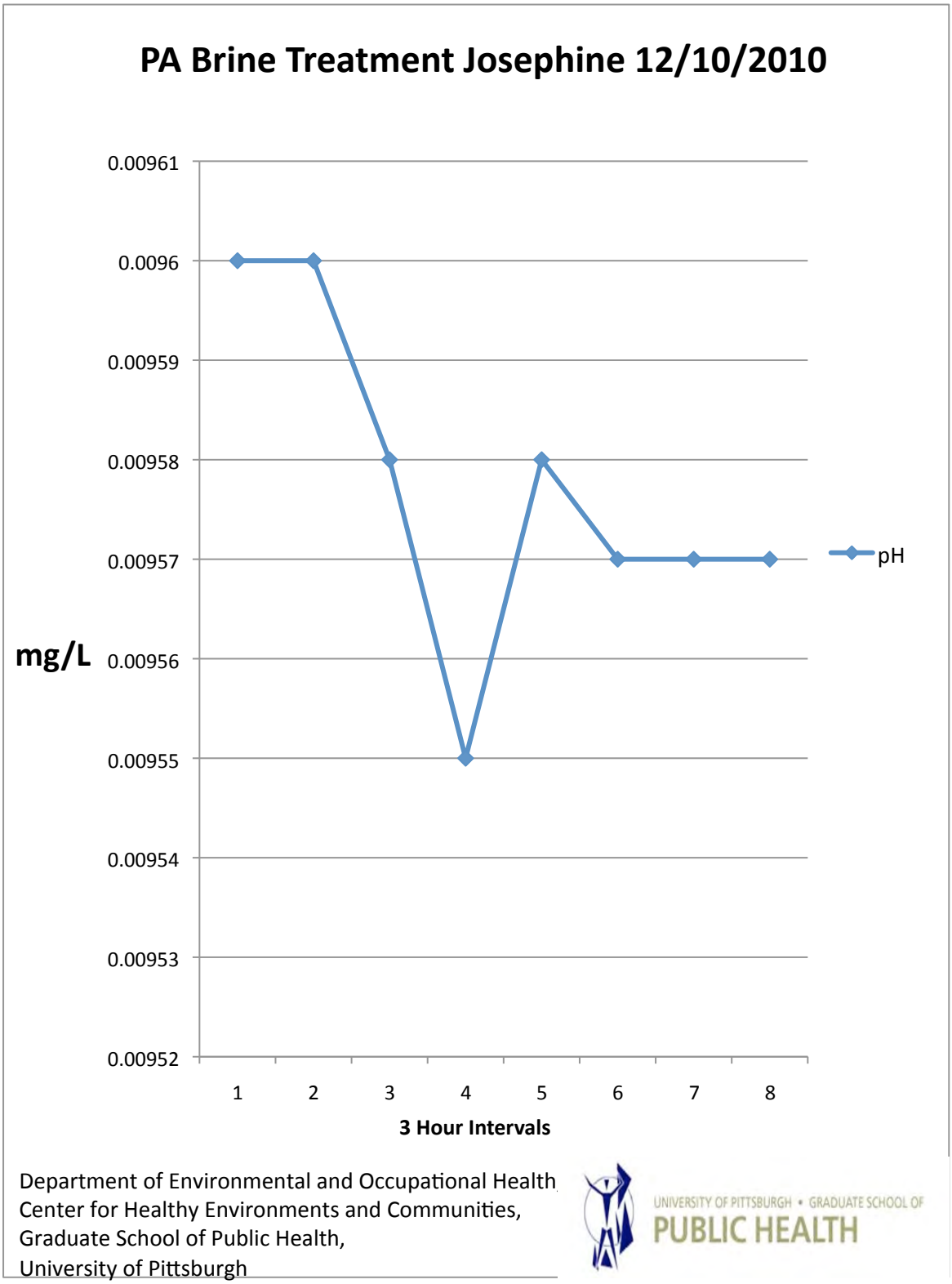

Figure 19. Time-plot of Benzene Concentration in Effluent from the PA Brine Josephine Facility [Sampling begins on 12/10/2010; Hour 1 begins at 11:00 (11:00 AM)]

Discussion

Levels of contaminants in effluent from the PBT - Josephine Facility are now interrpreted according to comparisons with applicable federal and state standards and recommended guidelines for both human and aquatic health. Please see Table 3, Federal and State Recommendations and Standards for Protection of Human and Aquatic Health for a complete list of comparison values by analyte found in PBT-Josephine effluent. Following is an explanation of important comparison values used in this report.

Table 3. Federal and State Recommendations and Standards for Protection of Human and Aquatic Health.

Analyte Standards										
Analytes	MCL_1 (mg/L)	$SMCL_1$ (mg/L)	CCC_2 (mg/L)	CMC_2 (mg/L)	Water & $Organism_2$ (mg/L)	$Organism\ Only_2$ (mg/L)	MRL: Acute Oral (mg/kg/day)3	MRL: Intermediate Oral $(mg/kg/day)_3$	MRL: Chronic Oral $(mg/kg/day)_3$	$Literature_{*4}$
Aluminum	NR	200	NR	NR	NR	NR	NR	1	1	NR
Arsenic	0.01	NR	0.15	0.34	0.000018	0.00014	0.005	NR	0.0003	NR
Barium	2	NR	4.1	21	1	1	NR	0.2	0.2	NR
Cadmium	0.005	NR	0.00025	0.002	NR	NR	NR	0.0005	0.0001	NR
Copper	1.3	NR	NR	NR	1.3	NR	0.01	0.01	NR	NR
Iron	NR	0.3	NR	NR	NR	NR	NR	NR	NR	NR
Lead)	0.015	NR	0.0025	0.065	NR	NR	NR	NR	NR	NR
Magnesium	NR	0.05	NR	NR	NR	NR	NR	NR	NR	NR
Manganese	NR	0.05	NR	NR	NR	NR	NR	NR	NR	NR
Nickel	NR	NR	0.052	0.47	0.61	4.60	NR	NR	NR	NR
Strontium	4*	NR	NR	NR	NR	NR	NR	2	NR	NR
Zinc	NR	5	0.12	0.12	7.4	26	NR	0.3	0.3	NR
Bromide	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.1*
Chloride	NR	250	230	860	NR	NR	NR	NR	NR	NR
Nitrate	10	NR	NR	NR	NR	NR	NR	NR	NR	NR
Sulfate	NR	250	NR	NR	NR	NR	NR	NR	NR	NR
Total Dissolved Solids	NR	500	NR	NR	NR	NR	NR	NR	NR	NR
Benzene	0.01	NR	0.64	0.13	0.0022	0.051	NR	NR	0.0005	NR
Ethylbenzene	0.7	NR	2.9	0.58	0.53	2.1	NR	0.4	NR	NR
Toluene	1	NR	0.33	1.7	1.3	15	0.8	0.02	NR	NR
Xylene	1	NR	1.1	0.21	NR	NR	1	0.4	0.2	NR
2-BE	NR	NR	NR	NR	NR	NR	0.4	0.07	NR	NR
pH (pH units)	NR	8.5	NR	NR	NR	NR	NR	NR	NR	NR

NR=No Reported Value *Recommended (ATSDR, 2011)

1. U.S. Environmental Protection Agency. Drinking Water Contaminants. Updated January 11, 2011. http://water.epa.gov/drink/contaminants/index.cfm#List. Accessed February 4, 2011.
2. U.S. Environmental Protection Agency. National Recommended Water Quality Criteria. Updated October 12, 2010. http://water.epa.gov/scitech/swguidance/waterquality/standards/current/index.cfm. Accessed February 4, 2011.
3. Agency for Toxic Substances and Disease Registry. Minimum Risk Levels (MRLs). December 2009. http://www.atsdr.cdc.gov/mrls/pdfs/atsdr_mrls_december_2009.pdf. Accessed February 22, 2011.
4. Bonacquisti, Thomas P. 2006. A drinking water utility's perspective on bromide, bromate, and ozonation. Toxicology. 2 (3). P. 145.

Table 4. Derived Minimum Risk Levels (MRL's) for Ingestion of Contaminants through Drinking Water

MRL Limits for Drinking Water Ingestion in Subpopulations							
Analytes:	Barium	Strontium	Benzene	Ethylbenzene	Toluene	Xylene	2-BE
Adult Male MRL for *Acute* Oral Exposure (mg/L/day)	NR	NR	NR	NR	27.55	34.44	13.77
Adult Male MRL for *Intermediate* Oral Exposure (mg/L/day)	6.89	68.87	NR	13.77	0.69	13.77	2.41
Adult Male MRL for *Chronic* Oral Exposure (mg/L/day)	6.89	NR	0.017	NR	NR	6.89	NR
Adult Female MRL for *Acute* Oral Exposure (mg/L/day)	NR	NR	NR	NR	23.07	28.84	11.53
Adult Female MRL for *Intermediate* Oral Exposure (mg/L/day)	5.77	57.67	NR	11.53	0.58	11.35	2.02
Adult Female MRL for *Chronic* Oral Exposure (mg/L/day)	5.77	NR	0.014	NR	NR	5.77	NR
Child Age 5, MRL for *Acute* Oral Exposure (mg/L/day)	NR	NR	NR	NR	12.18	15.22	6.09
Child Age 5, MRL for *Intermediate* Oral Exposure (mg/L/day)	3.04	30.45	NR	6.09	0.30	6.09	1.07
Child Age 5, MRL for *Chronic* Oral Exposure (mg/L/day)	3.04	NR	0.008	NR	NR	3.04	NR

The U.S. EPA's National Recommended Water Quality Criteria are published pursuant to Section 304(a) of the Clean Water act (CWA) as recommended guidelines for states adopting water quality standards. These criteria are specific to ambient surface water quality for the protection of ecological and human health. The criteria include a Criterion Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) for both freshwater and saltwater environments. The CMC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. The CCC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.

Also derived are criteria for surface water concentrations to preserve human health during the consumption of "aquatic organisms only", or consumption of "aquatic organisms with surface water". This Human Health Ambient Water Quality Criteria (AWQC) designates "the highest concentration of a pollutant in water that is not expected to pose a significant risk to human health."(U.S. EPA, 2010) The U.S. EPA sets two Ambient Water Quality Criteria (AWQC) standards, one for protection from ingesting water and aquatic organisms, and another for protection from ingesting only the aquatic organism. The standard is measured in surface water, and the concentration of pollutant in the water is typically higher than the concentration in the organism. Therefore the surface water standard must be lower when water is consumed with the organism (U.S. EPA, 1999).

Minimum Risk Levels (MRLs) as established by the Agency for Toxic Substances and Disease Registry (ATSDR) are also included for the analytes. An MRL is an estimate of "daily human exposure to a hazardous substance that is not likely to pose an appreciable risk of adverse noncancer health effects" (ATSDR, 2009). Proposed MRLs are only accepted after rigorous review, but are still subject to change as new toxicological information becomes available. Most of the dose-response modeling for these substances is based on animal studies. When the MRLs are derived for human exposures, they contain some degree of uncertainty especially for the people who might be most sensitive. The uncertainty in the interspecies relationship, as well as the intra-species variability are incorporated into the derivation of MRL's using an uncertainty factor. ATSDR uses a conservative approach in applying uncertainty factors due to the lack of precise toxicological information for human responses(ATSDR, 2009).

Table 3, presents all found ATSDR MRL's for each contaminant in this study by categories of acute, intermediate and chronic length exposure. Generally acute exposure MRL's are greater than intermediate exposure MRL's, which in turn are greater than chronic exposure MRL's. In Table 3, ATSDR MRL's are presented with units of mg/kg/day, which represents mg pollutant / kg body weight / day. Before these ATSDR MRL's are used as comparison values in this discussion they required derivations based on the body weight of important population subgroups and the average volume that each subpopulation drinks per day. We choose to do these derivations for the population groups adult men (ages 18-75), adult women (ages 18-75), and for children at age 5. The EPA Exposure Factors Handbook was used as a reference (U.S.EPA, 1997, Table 7-2, 7-4) where the mean for body weight for men ages 18-75 is 78.1 kg and for women of the same ages is 65.4 kg, and the mean bodyweight for children, at 5 years of age, combining boys and girls is 19.7 kg. To account for the different groups intakes of water we also referred to the EPA Exposure Factors Handbook; we choose to use the 90^{th} percentile of the water intake ranges for each population group, so male and female adults (ages 20-64) were grouped with the same intake rate of 2.268 L/day, for children age 5 we used 1.294 L/day (ages 1-10). Table 4, Derived Minimum Risk Levels (MRL's) for Ingestion of Contaminants through Drinking Water presents all derived MRL's for each contaminant in drinking water by length of exposure and by population subgroup. These derived values will be used to compare to applicable contaminant levels in PBT-Josephine Facility effluent in the discussion that follows.

Maximum Contaminant Levels (MCLs) and Secondary Maximum Contaminant Levels (SMCLs) are also provided for analytes, when applicable. The MCL is a National Primary Drinking Water Regulation (NPDWR) standard for Public Water Systems (PWS) established under the Safe Drinking Water Act (SDWA) by the U.S. EPA. The MCL sets a legal threshold limit for concentrations of pollutants in a PWS. MCLs are established through a cost-benefit analysis of treatment techniques, and are set as close to the Maximum Contaminant Level Goals (MCLG's), or reference doses, as possible (U.S. EPA, 2011). The regulations for NPDWRs can be found in 2002 CFR Title 40 Volume 19 Chapter 1 Part 141 of the Code of Federal Regulations. SMCLs are included under the National Secondary Drinking Water Regulations (NSDWRs), which are "non-enforceable guidelines that regulate pollutants that can cause cosmetic effects, such as skin or tooth

discoloration, or aesthetic effects to the drinking water, including taste, color, and odor" (U.S. EPA, 2011).[2]

This discussion will first compare effluent contaminant concentrations, which have established criteria for human health. Each contaminant with human health criteria will be discussed first in terms of comparisons to established human health criteria levels and second to any published ecological health criteria levels. Contaminants with secondary drinking water standards or aquatic health criteria alone are addressed following contaminants with published human health criteria levels.

Barium

Barium had a mean concentration in effluent of 27.3 ppm (maximum of 37 ppm). The mean Ba level is approximately 14 times the maximum concentration limit (MCL) of Ba in drinking water of 2 ppm. National Primary Drinking Water Regulations (NPDWRs or primary standards) set MCL's as legally enforceable standards that apply to public water systems, from groundwater or surface water sources. MCL's are not always set according to health-based outcomes alone but may be influenced by available technology to meet health-based objectives. All the following contaminants will be compared to primary drinking water standards when applicable; this is done not to imply that people are drinking water from the outfall, but to give an important value for comparison purposes. MCL's do not apply to private well water users.

People are judged at risk if they consume" water and aquatic organisms" or "aquatic organisms only" from water with contaminant concentrations over established criteria. The consumption concentration of "water and organism" for barium is 1 ppm and for "organism alone" is 1 ppm. The levels of barium in the effluent are over 27 times these criteria. "Water and organism" and "organism only criteria" are compared to all effluent contaminant concentrations when applicable because anglers fish Blacklick Creek and the downstream and upstream watersheds.

The Agency for Toxic Substances and Disease Registry (ATSDR) has developed Minimal Risk Levels (MRLs) as an initial response to its mandates contained in The

[2] The guidelines for NSDWRs can be found in 2002 CFR Title 40, Volume 19, Chapter 1 (Part 143) of the Code of Federal Regulations (U.S. EPA, 2011).

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [42 U.S.C. 9604 et seq.], as amended by the Superfund Amendments and Reauthorization Act (SARA) [Pub. L. 99 499]. ATSDR has developed a practice similar to that of the EPA's Reference Dose (RfD) and Reference Concentration (RfC) for deriving substance specific health guidance levels for non-neoplastic endpoints. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure, and they are intended to serve as screening levels to be used by ATSDR health assessors to identify contaminants and potential health effects that may be of concern at hazardous waste sites. The ATSDR MRL's for barium for oral intermediate exposure and oral chronic exposure are .2 mg/kg/day, both for renal endpoints. These MRL's are for soluble barium salts; it is currently not known what form of barium predominates in the outfall effluent or in receiving water after mixture, however it is likely that barium sulfate, which is insoluble, will predominate in Blacklick Creek due to its high sulfate content. Thus, the presented barium MCL's represent the most conservative case. The derived minimum risk levels for barium in drinking water (from Table 4) for both intermediate and chronic exposure are 6.89 mg/L/day, 5.77 mg/L/day, and 3.04 mg/L/day for adult men, adult women, and children, respectively. The mean concentration of barium in PBT-Josephine effluent water (27.3 ppm) is 3.96 times the derived drinking water MRL for intermediate and chronic exposures for adult men; 4.73 times the derived drinking water MRL for intermediate and chronic exposures for adult women; and 8.98 times the derived drinking water MRL for intermediate and chronic exposures for children.

The Environmental Protection Agency's Criteria Maximum Concentration (CMC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. The Criterion Continuous Concentration (CCC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. The CMC and CCC are just two of the six parts of an aquatic life criterion; the other four parts are the acute averaging period, chronic averaging period, acute frequency of allowed exceedence, and chronic frequency of allowed exceedence. Because 304(a) aquatic life criteria are national guidance, they are intended to be protective of the vast majority of the aquatic communities in the United States. The CMC for barium in water for the protection of aquatic health is 21 ppm, which is well below (.77 times) the mean concentration of barium exiting

the PBT Josephine outfall of 27.3 ppm. The CCC for barium in water is 4.1 ppm; the mean concentration of barium discharged into Blacklick Creek is 6.66 times the barium CCC.

According to the facility's NPDES permit the "Average Monthly" Ba concentration in effluent can be as high as 114 mg/L, and the "Maximum Daily" concentration in effluent can be as high as 228 mg/L. The permitted limits of Ba in effluent do not account for known risk levels of Ba to human and aquatic health in the mixing distance downstream of the effluent pipe and they do not take into account that drinking water wells are immediately downstream, which can capture surface water from the stream when well pump rates are sufficiently high.

Strontium

The recommended EPA level for Sr in finished municipal drinking water is 4 ppm, and the mean concentration of Sr in PBT-Josephine effluent water is 2981.1 ppm. The mean concentration of strontium in PBT-Josephine effluent water is over 745 times the recommended EPA level. The strontium ATSDR MRL for oral route, intermediate exposure is 2 mg/kg of body mass/day, for musculoskeletal endpoints. The derived minimum risk levels for strontium in drinking water (from Table 4) for intermediate exposure for adult men, adult women, and children are 68.87 mg/L/day, 57.67 mg/L/day, and 30.45 mg/L/day, respectively. The mean concentration of strontium in PBT-Josephine effluent water (2981.1 ppm) is 43.29, 51.68 and 97.90 times the derived strontium drinking water MRL for intermediate exposures for adult men, adult women, and children, respectively. The maximum level of strontium leaving the outfall into Blacklick Creek was 3120 ppm; this concentration is 45.30, 54.10, and 102.46 times the derived strontium drinking water MRL's for adult men, adult women, and children, respectively. There are no reported EPA human consumption criteria or aquatic criteria CMC or CCC's for strontium.

Strontium is not listed on the PBT-Josephine Facility NPDES permit, but the facility is required to notify the PA DEP if they routinely discharge 100 ppb of a toxic pollutant or nonroutinely discharge 500 ppb of a toxic pollutant. The mean concentration of Sr in effluent water of 2981.1 ppm is 29,811 and 5,962 times the lower and upper notification levels required by the PA DEP NPDES permit, respectively. Searches of the PA DEP file for December, 2010, which is contained in Appendix A, shows no such notification to the DEP.

Bromide

Bromide in water is of concern because of its ability to form brominated analogs of drinking water disinfection by-products (DBP). DBP's are formed when disinfectants like chlorine, ozone, chlorine dioxide, and chloramine react with natural organic matter and/or other halogens like bromide and iodide in the source water. Specifically, bromide can be involved in reactions between chlorine and naturally occurring organic matter in drinking-water, forming brominated and mixed chloro-bromo byproducts, such as trihalomethanes or halogenated acetic acids, or it can react with ozone to form bromate. There have been hundreds of DBPs identified in drinking water, including many brominated organic compounds; only about 50% of the total organic halides in chlorinated drinking water have been identified. Several DBPs have been linked to cancer in laboratory animals and as a result the U.S. EPA has regulated some DBP's.

There is general agreement that background bromide levels in fresh-water sources be kept at about 100 ppb, which is .1 ppm (Bonacquisti, 2006). Therefore regulatory authorities and water treatment plant operators become concerned when there are sources of bromides in a surface water system adding to this level. The PBT- Josephine facility discharges effluent into Blacklick Creek with a mean level of bromide of 1068.8 ppm, which is 1,068,800 ppb; this is 10,688X the 100 ppb level at which authorities become concerned. There are no reported EPA aquatic health criteria for bromide –however it has chemical properties similar to chloride and chloride has a secondary MCL, based on taste, a freshwater CCC, and freshwater CMC of 250 ppm, 230 ppm and 860 ppm, respectively. The mean effluent bromide level from the PBT –Josephine facility of 1068.8 is above all these chloride criteria.

Bromide is not listed on the PBT-Josephine Facility NPDES permit, but the facility is required to notify the PA DEP if they routinely discharge 100 ppb of a toxic pollutant or nonroutinely discharge 500 ppb of a toxic pollutant. The mean concentration of Br in effluent water 1068.8. ppm is 10,688 and 2,138 times the lower and upper notification levels required by the PA DEP NPDES permit, respectively. Searches of the PA DEP file for December, 2010, which is contained in Appendix A, shows no such notification to the DEP.

Benzene

The mean level of benzene, a known carcinogen, in outfall effluent from PBT-Josephine was 0.012 ppm or 12 ppb. The drinking water MCL for benzene is 5 ppb, thus effluent levels were above twice the drinking water MCL. The EPA consumption "water and organism" risk level for benzene is 2.2 ppb in water, the mean benzene level in PBT-Josephine effluent water is almost 6 times this criteria; the "organism only" risk level for benzene is 50 ppb in water, the mean level of benzene in effluent water is 24% of this guideline. The EPA CMC and CCC for aquatic organisms for benzene were not exceeded in effluent water, the mean benzene level in PBT-Josephine effluent water is 1.9% of the EPA CCC for benzene and 9.23% of the EPA CMC for benzene. The benzene ATSDR MRL for oral route, chronic exposure is 0.0005 mg/kg of body mass/day, for immunological endpoints. The derived minimum risk levels for benzene in drinking water (from Table 4) for chronic exposure for adult men, adult women, and children are 0.017 mg/L/day, 0.014 mg/L/day, and 0.008 mg/L/day, respectively. The mean concentration of benzene in PBT-Josephine effluent water (0.012 ppm) is 70% of, 86% of, and 1.5 times the derived chronic drinking water MRL for benzene for adult men, adult women, and children, respectively.

Ethylbenzene

The mean level of ethylbenzene in effluent water (0.002 ppm) was 35% of the drinking water MCL. The consumption "water and organism" (0.53 ppm) and "organism only" (2.1 ppm) risk levels in water for ethylbenzene are at least 2 orders of magnitude above the mean level of ethylbenzene in effluent water. The mean level of ethylbenzene in effluent was only a small fraction of the EPA CMC (2.9 ppm) and CCC (.59 ppm) for ethylbenzene. The ethylbenzene ATSDR MRL for oral route, intermediate exposure is 0.4 mg/kg of body mass/day, for hepatic endpoints (uncertainly factor 30). The derived minimum risk levels for ethylbenzene in drinking water (from Table 4) for intermediate exposure for adult men, adult women, and children are 13.77 mg/L/day, 11.53 mg/L/day, and 6.09 mg/L/day, respectively. The mean concentration of ethylbenzene in PBT-Josephine effluent water (0.002 ppm) is at least over three orders of magnitude below the lowest derived minimum risk level for ethylbenzene for children.

Toluene

The mean level of toluene was 0.025 ppm in effluent water, which is2.5% of the EPA MCL for toluene (1ppm), 7.5% of the consumption “water and organism” risk level, and 1.5% of the consumption “organism only” risk level. The toluene CCC is .33 ppm and CMC is 1.7 ppm, which are both at least one order of magnitide above the concentration of toluene measured in the effluent. The toluene ATSDR MRL for oral route, acute exposure is 0.8 mg/kg of body mass/day, and for intermediate exposure is 0.02 mg/kg/day, both for neurological endpoints and both with uncertainty factors of 300. The derived minimum risk levels for toluene in drinking water (from Table 4) for acute exposure for adult men, adult women, and children are 27.55 mg/L/day, 23.07 mg/L/day, and 12.18 mg/L/day, respectively. The mean concentration of toluene in PBT-Josephine effluent water (0.025) is over 2 orders of magnitude below the lowest derived acute MRL for toluene in drinking water for children. The derived minimum risk levels for toluene in drinking water (from Table 4) for intermediate exposure for adult men, adult women, and children are 0.69 mg/L/day, 0.58 mg/L/day, and 0.30 mg/L/day, respectively. The mean concentration of toluene in PBT-Josephine effluent water (0.025) is 3.6%, 4.3%, 8.3% of the derived MRL’s for toluene in drinking water for adult males, adult females, and children, respectively.

Xylenes

The mean of xylenes in effluent water was 0.028 ppm or 28 ppb, which is 2.8% of the drinking water MCL of 1 ppm. The mean of xylenes in effluent water was 13.3% of the consumption “water and organism” risk level of .21 ppm and 2.5% of the “consumption only” risk level of 1.1 ppm.. The EPA CCC and CMC for xylenes for protection of aquatic life are .33 ppm and 1.7 ppm, respectively. Xylenes concentration in the effluent was about 1 order of magnitude lower than the CCC, and 2 orders of magnitude below the CMC standard. The xylenes (mixed) ATSDR MRL for oral route, acute exposure is 1.0 mg/kg of body mass/day, and for intermediate exposure is 0.4 mg/kg/day, and for chronic exposure is .2 mg/kg/day, while all are for neurological endpoints-the acute MRL has an uncertainly factor of 100 and both the intermediate and oral MRL’s have an uncertainly factor of 1000. The derived minimum risk levels for xylenes (mixed) in drinking water (from Table 4) for acute exposure for adult men, adult women, and children are 34.44 mg/L/day, 28.84 mg/L/day, and 15.22 mg/L/day, respectively. The derived minimum risk levels for xylenes (mixed) in drinking water (from Table 4) for intermediate exposure for adult men, adult women, and children are 13.77 mg/L/day, 11.35 mg/L/day, and 6.09 mg/L/day, respectively. The derived

minimum risk levels for xylenes (mixed) in drinking water for chronic exposure for adult men, adult women, and children are 6.89 mg/L/day, 5.77 mg/L/day, and 3.04 mg/L/day, respectively. The mean concentration of xylenes in PBT-Josephine effluent water (0.028 ppm) is over 2 orders of magnitude below the lowest derived minimum risk level for acute exposure, which is to children at 15.22 mg/L/day; 0.46% of the xylenes derived intermediate exposure MRL to children; and 0.92% of the xylenes derived chronic exposure MRL to children.

2-butoxyethanol

2-butoxyethanol is a glycol ether commonly called Butyl Cellosolve, and is an added chemical in slick-water hydrofracturing of Marcellus Shale deposits, where it is used as an anti-foaming and anti-corrosion agent and emulsifier. The mean and maximum levels of 2-BE found in the PBT – Josephine effluent were 59 ppm and 66 ppm, respectively. There is no drinking water MCL for 2-BE however the ATSDR publishes screening level minimun risk levels for acute and intermediate exposure to 2-BE. The 2-BE ATSDR MRL for oral route, acute exposures is 0.4 mg/kg/day based on hematological effects, with an uncertainty factor of 90; the 2-BE MRL for oral route, intermediate exposure is 0.07 mg/kg/day and it is based on hepatic health endpoints with an uncertainty factor of 1000. The derived minimum risk levels for 2-BE in drinking water (from Table 4) for acute exposure for adult men, adult women, and children are 13.77 mg/L/day, 11.53 mg/L/day, and 6.09 mg/L/day, respectively; the derived MRL's for 2-BE in drinking water for intermediate exposure for adult men, adult women, and children are 2.41 mg/L/day, 2.02 mg/L/day, and 1.07 mg/L/day, respectively.

The mean concentration of 2-BE in PBT-Josephine effluent water (59 ppm) is 4.28, 5.12, and 9.69 times the derived 2-BE drinking water MRL's for acute exposure to adult males, adult females, and children respectively. The mean concentration of 2-BE in PBT-Josephine effluent water is 24.48, 29.21, and 55.14 times the derived 2-BE drinking water MRL's for intermediate exposure to adult males, adult females, and children, respectively.

2-BE is not listed on the PBT-Josephine Facility NPDES permit, but the facility is required to notify the PA DEP if they routinely discharge 100 ppb of a toxic pollutant or nonroutinely discharge 500 ppb of a toxic pollutant. The mean concentration of 2-BE in effluent water 59 ppm is 590 and 118 times the lower and upper notification levels, required by the PA DEP NPDES permit, respectively.

Searches of the PA DEP file for December, 2010, which is contained in Appendix A, shows no such notification to the DEP.

Other Contaminants and Water Quality Variables - Contaminants with Secondary MCL's and Aquatic Receptor Effects

Magnesium was found in the effluent with a mean of 1,247.5 mg/L. The SMCL for magnesium concentration in drinking water is .05 mg/L. The mean concentration of magnesium measured in samples was 24,950 times the SMCL. The mean concentration of manganese in the effluent was 0.08 mg/L and the maximum concentration detected was 0.15 mg/L. The SMCL for manganese concentration in drinking water is .05 mg/L; the mean effluent concentration of manganese is 160% and the maximum concentration in effluent of manganese is 300% of the manganese drinking water SMCL. The mean concentration of chlorides in the effluent was 117,625 mg/L; 470.5 times the SMCL for chlorides in drinking water of 250 mg/L. To protect aquatic communities, the CMC for chlorides in surface water is 860 mg/L, and the CCC for chlorides in surface water is 230 mg/L. The mean concentration of chlorides measured in samples was 138 times the CMC and 511 times the CCC. The mean concentration of sulfates in the effluent was 560 mg/L; the effluent mean concentration of sulfates is 2.2 times the SMCL for sulfates in drinking water (250 mg/L). The SMCL for total dissolved solids (TDS) in drinking water is 500 mg/L, and the mean concentration of TDS measured in samples was 186,625 mg/L; the mean concentration of TDS in effluent water is 373 times the SMCL.

Calcium is a major cation in natural gas wastewater and has a mean concentration of 16,300 mg/L in the effluent. The mean concentration of iron in effluent was .13 mg/L, which is 43% of the SMCL for iron concentration in drinking water (.3 mg/L). Sodium is a major cation in natural gas wastewater and has a mean concentration of 39,712.95 mg/L in the effluent. The mean concentration of Potassium in the effluent was 1,336.25 mg/L.

Exceedence of CMC's and CCC's in surface water will have an impact on aquatic communities, as well as the terrestrial communities that utilize the aquatic resources. These standards are set to protect the surface water environment; therefore the standards are set as concentrations in surface water and are not applicable to the effluent from the PBT-Josephine facility. However, it is reasonable to assume that contaminants from the PBT-Josephine effluent are impacting the immediate downstream section of Blacklick Creek. Figure 20, Kriged

Concentrations of Total Dissolved Solids Upstream and Downstream of the PBT – Josephine Facility Effluent Outfall and Figure 21, Kriged Concentrations of Salinity Upstream and Downstream of the PBT – Josephine Facility Effluent Outfall show that TDS and salinity in the stream water remain elevated over baseline levels to the full extent of probe monitoring downstream. Monitoring was conducted using a Hanna Instruments surface water multi-parameter probe, model HI-9828.

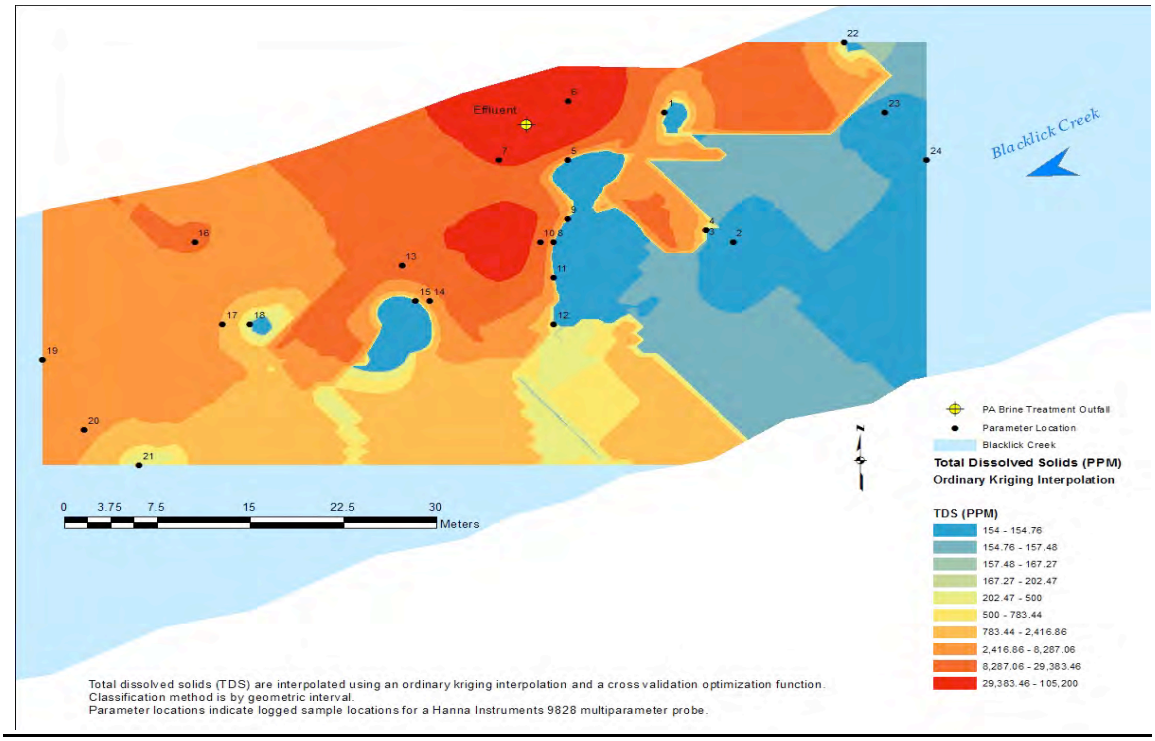

Figure 20. Kriged Concentrations of Total Dissolved Solids Upstream and Downstream of the PBT – Josephine Facility Effluent Outfall

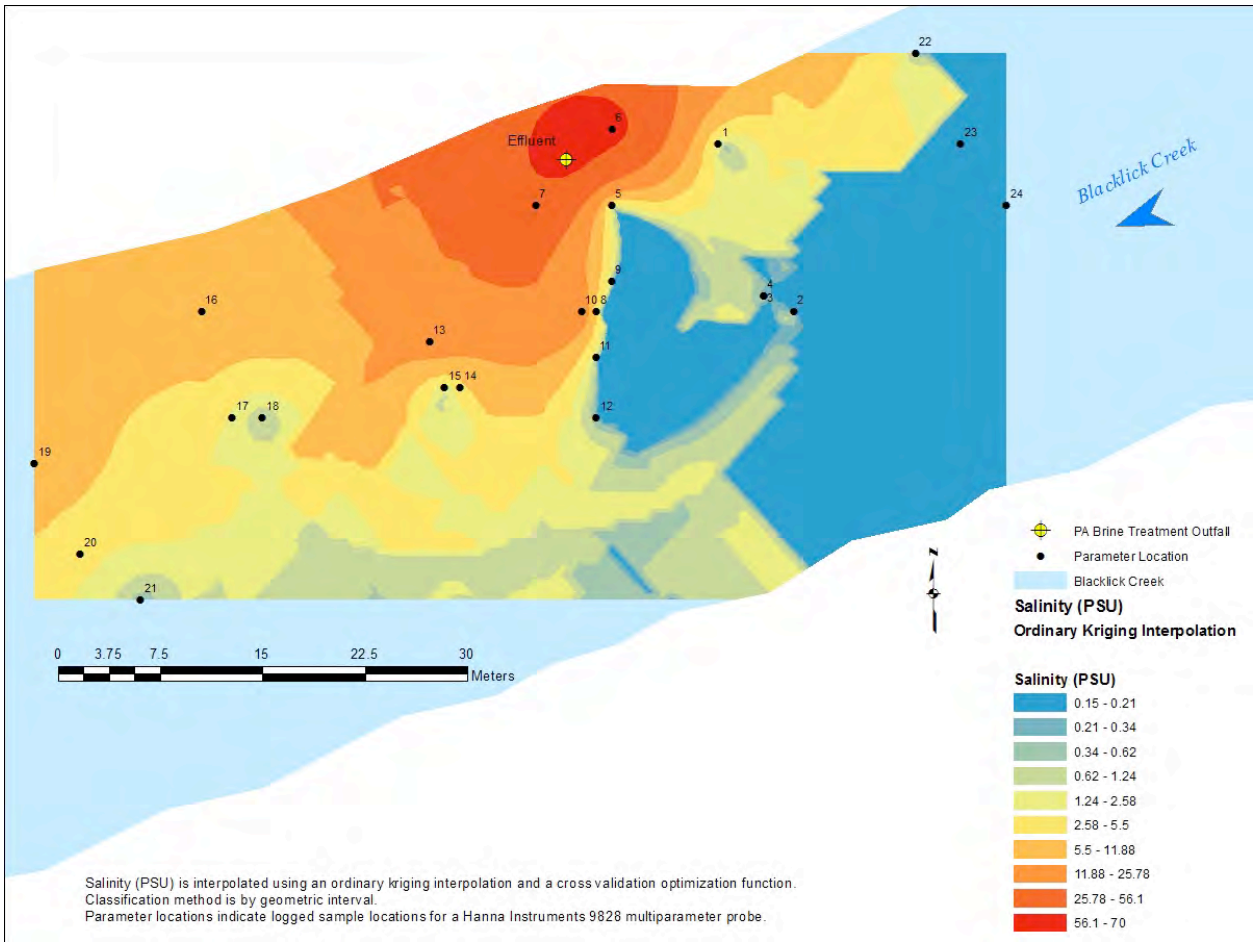

Figure 21. Kriged Concentrations of Salinity Upstream and Downstream of the PBT – Josephine Facility Effluent Outfall

Comparisons of PBT- Josephine Facility Effluent Concentrations of Contaminants to NPDES Permited Discharge

The PBT-Josephine facility's National Pollutant Discharge Elimination System (NPDES) permit was granted by the Pennsylvania, Department of Environmental Protection (PA DEP) on July 1, 2008. Table 1 shows discharge limitations for specific pollutants as well as effluent monitoring requirements. Pollutants with discharge limits include total iron, oil and grease, total suspended solids (TSS), barium and pH. Total iron discharge levels are to be maintained at an average monthly level of 3.5 ppm, not to exceed a maximum instantaneous level of 7 ppm. The mean level of iron found in effluent in our December sampling period was 0.13 ppm, which is well over 1 order of magnitude below discharge limits. We did not analyze sampled effluent wastewater for oil and grease or TSS, however

we did analyze for pH and found a 24 hour mean of 9.58 standard units, with a maximum of 9.6 units. The measured pH is thus slightly over discharge limits by 0.08 standard units.

The facility is permitted to discharge Ba at a monthly average of 114 ppm and a daily maximum of 228 ppm. The daily mean level of Ba from our sampling regime, which differs from the NPDES monitoring regime, was 27.3 ppm with a maximum of 37 ppm and a minimum of 20 ppm. The level of barium found was below the discharge limitations by almost a factor of 10. Barium is precipitated out of the flowback water using sulfate, additionally high sulfate in Blacklick Creek from abandoned mine drainage is available to react with barium entering the stream and will form barium sulfate, which is practically insoluble in water. Since the toxicity and bioavailability of barium is highly dependent on its solubility in water it is unlikely that barium toxicity or bioaccumulation will occur in aquatic species in this stream system (Menzie, C.A. et al., 2008). However, barium is exiting this plant in a very Cl rich effluent and may form the compound barium chloride, which is water soluble and more toxic. The relative amounts of water insoluble compounds like barium sulfate and water soluble compounds like barium chloride or even barium bromide (bromide is found in the effluent at up to 1100 ppm) are unknown within the full mixing interval of Blacklick Creek. We question the PA DEP's reasoning in granting a permit to discharge barium along with extremely high levels of chloride and elevated levels of bromide in effluent water as there could be effects on aquatic organisms, at least within the mixing interval.

The DEP permit allows the PBT-Josephine plant to discharge unlimited levels of chloride and TDS into Blacklick Creek, and only requires monitoring and reporting of these discharges. We question the DEP's decision to grant unlimited discharge of Cl and TDS in a smaller flow stream such as Blacklick Creek, especially since Cl levels within the mixing volume, could distress aquatic life (see Figure 21, which shows persistent salinity increases downstream of the effluent outfall, over background levels above the effluent discharge point). The DEP seems not to have incorporated any appreciation of Blacklick Creek low flow periods into the Cl discharge requirements. Figure 22, Discharge of Blacklick Creek from April 2010 to March 2011 shows the daily discharge of Blacklick Creek in cubic feet per second (cfs) as obtained from the USGS National Water Information System: Web Interface. Daily discharge varies tremendously, reaching a low of about 25 cfs in September of 2010 and a recent high of over 9000 cfs in February of 2011. This constitutes a water discharge range of about 8,975 cfs with highest flow being

360 times the lowest flow recording (USGS, 2011). The DEP should have accounted for periods of relative low creek flow when setting discharge limits for Cl.

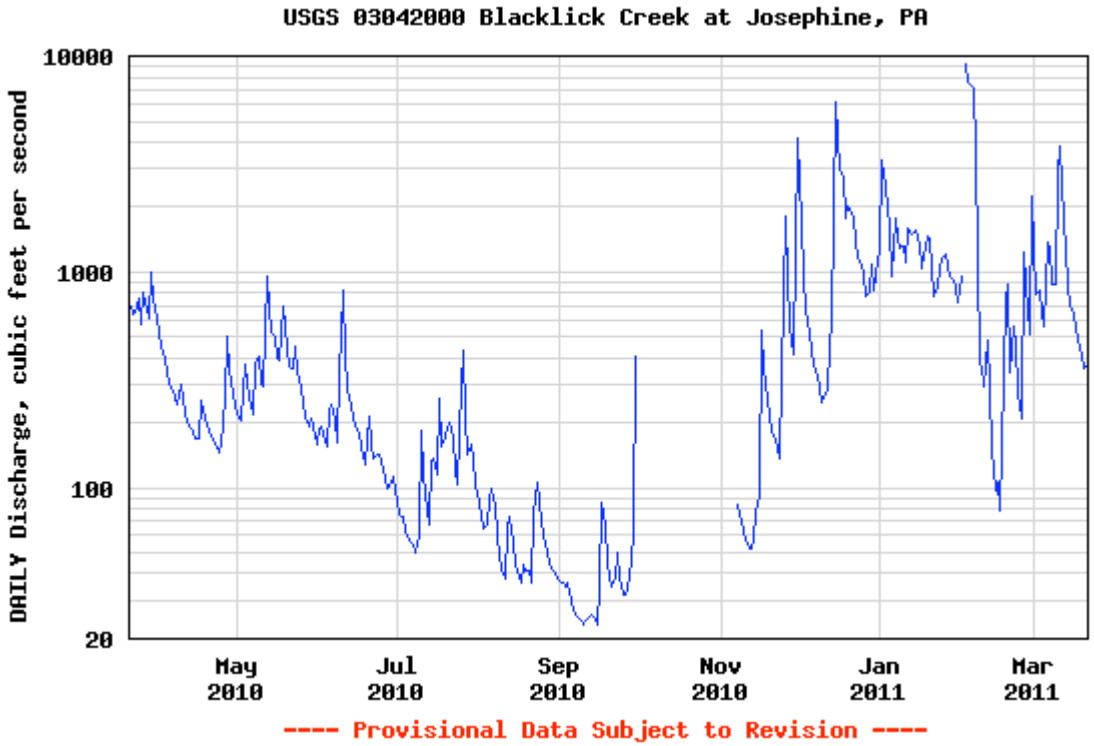

Figure 22. Discharge of Blacklick Creek from April 2010 to March 2011

TDS is a measurement of inorganic salts, organic matter and, other dissolved materials in water and the measurement of TDS does not differentiate among ions or contaminants. It is thus a nonspecific indicator of water quality. Nevertheless it can indicate high levels of contaminants in effluent water that can affect human and aquatic health. It should be noted that new or expanded discharges of TDS in Pennsylvania are limited to discharging only 500 mg/L of TDS as a monthly average. A better method for determining a level of TDS that can be accommodated in streams is to use a site-specific approach, as codified in Iowa law [IAC 61.3(a)g]. Iowa requires that if a facilities discharge causes a TDS concentration above 1000 mg/L then acute toxicity tests are required to demonstrate that the discharge will not result in toxicity to aquatic life at an in-stream concentration of greater than 1,000 mg/L. The demonstration consists of collecting a sample of the discharge and having a laboratory perform a whole effluent toxicity (WET) test on it, the results of the WET test are then used to determine effluent limits for TDS in a facilities NPDES permit.

Contaminants of major concern that were detected in this study of effluent fluids from the PBT –Josephine Facility and are not listed on their NPDES permit are strontium, bromide, benzene, ethylbenzene, toluene, xylenes, and 2-BE. Contaminants in this group of particular concern because they are discharged over 100 µg/L or 100 ppb (a provision in the PBT-Josephine NPDES discharge permit requires the facility to notify DEP if they discharge a toxic pollutant over 100 ppb) are strontium, bromide and 2-BE. Additionally, the facility is also required to notify the PA DEP if they release 500 µg/L of any toxic pollutant on a nonroutine, infrequent basis. Levels of strontium, bromide and 2-BE are all at least 2 orders of magnitude over this reporting requirement. Additionally, known contaminants of major human and aquatic health concern were not addressed at all in the PBT-Josephine NPDES permit, even though it is well known that Marcellus Shale flowback fluids are enriched in many cations, anions, organic compounds and even radionuclides. Also, many chemicals are added to water, to make it slick-water that could be present in flowback water received for treatment by the facility. It is hard to understand the DEP's reasoning in not at least reevaluating this permit based on the recent report by the Gas Technology Institute (Hayes, 2009) that shows levels of strontium and other contaminants in flowback water over both the 100 and 500 ppb requirements set in the permit. It also seems reasonable to require the plant operator know what levels of cations, anions, and chemicals of particular toxicological importance are in flowback fluids and other oil and gas waste fluids so that they can insure proper treatment and discharge of waste, according to the terms of their discharge permit.

Masses of Contaminants Entering Blacklick Creek

The CHEC has information from the Pennsylvania, Department of Environmental Resources that the Pennsylvania Brine Treatment – Josephine Facility treated 15,728,241 gallons of oil and gas wastewater in the 6-month period from July 1, 2010 to December 31, 2010. Using this figure as the amount of effluent wastewater exiting the Josephine outfall and using the mean level of each contaminant found in the effluent over the sampling period of the study, the masses of contaminants with important human and ecological consequences discharged from the PBT – Josephine Facility into Blacklick Creek in the last 6 months of 2010 were as follows; barium - 1627 kg (3588 pounds); strontium - 177,712 kg (391,856 pounds; 196 tons); bromides -63,708 kg (140,476 pounds; 70.2 tons); chloride – 7,011,631 kg (15, 460,646 pounds; 7,730 tons); sulfate – 33,382 kg (73,607 pounds; 36.8 tons); 2 butoxyethanol – 3517 kg (7,755 pounds;

3.88 tons) and total dissolved solids – 11,124,733 kg (24,530,036 pounds; 12,265 tons).

Often arguments are made that all we really need to do is to dilute high concentrations of contaminants before they are discharged to surface water sources so that human health and the environment are protected. This reasoning misses the point that the masses of contaminants going into water from industrial sources remain constant even when they are diluted and the flow of water increases. It is the mass of contaminant put into any particular surface water source that is the most important determinant of buildup of the contaminant in the overall stream system and very importantly in stream sediments and pore water. The mass of contaminant discharged is thus a key in determining bioconcentration in fish and even potential exposure to private well water users, from wells bordering the stream.

It is useful here to give some comparison to road salt in the form of NaCl; NaCl has an atomic weight of 58.44 grams per mole—and the Chloride ion makes up about 60.7% of the compound by weight. NaCl in water dissolves readily to form the sodium and chloride ions and is a concern from road runoff for aquatic life. The state of New York used about 16.6 tons of NaCl per lane per mile per year in 1993 to clear roads of snow, which is put down at about 225 pounds per lane mile each time there was a light snow over the winter season year. The tonnage of Cl coming out of the PBT-Josephine Plant over the last 6 months of 2010 was 7,730; it is thus equivalent to the amount of chloride ion in 12,735 tons of NaCl. 12,735 tons of NaCl would cover approximately 767 lane miles per year in the event of any small snowfall at coverage of 255 pounds per lane per mile-over an entire snow year. This amount of Chloride was discharged into Blacklick Creek at one point over a 6-month period. Every day about 83,346 pounds of Chloride is entering Blacklick Creek –enough to cover 538 lane miles per snowfall.

Potentially Exposed Populations

Figure 5 shows the relative location of the PBT-Josephine Facility to a Rails-to-Trails pathway making it accessible to recreationalists and to anglers. Additionally note the plume of wastewater visible on the satellite image coming from the PBT-Josephine effluent outfall along the stream's right descending bank. Recreationalists are at high risk of being exposed to outfall contaminants through ingestion, inhalation and through the skin entry route. While the pH of outfall water will not cause irreversible eye damage at the maximum observed level of

10 pH units; irritation of the eyes and mucous membranes may occur. The outfall of the PBT- Josephine Facility is within easy access by users of nearby Rails-to-Trails pathways. Although not trout stocked of late by the Pennsylvania Fish and Boat Commission, there are indications that anglers frequent the area. Also children wade and swim in the creek during warmer weather and regional watershed websites indicate that paddlers use the creek for canoeing and kayaking. 2-BE, released into Blacklick Creek, may be ingested by swimmers in the creek; it can become airborne and present an inhalation hazard to anglers, swimmers and boaters; and it is taken in to the body through the skin. 2-BE deposited in stream sediments may take appreciably longer to degrade than 2-BE in surface water (7-28 days) because aerobic biodegradation is the predominant transformation process (ATSDR, 1998). Therefore waders, children, and anglers coming in contact with stream sediments could be exposed to 2-BE through skin absorption. Anglers taking and eating fish from upstream or downstream of the effluent outfall are at risk for exposure to multiple contaminants in the effluent water. However, 2-BE bioconcentration factors (BCFs) estimated from quantitative structure-activity relationships show that its bioconcentration in aquatic organisms is not a significant process (ATSDR, 1998).

Figure 23, Focused Map of PBT-Josephine Facility on Blacklick Creek and Area Water Wells and Springs, shows a close-up view of the receiving stream –Blacklick Creek-and its convergence with the Conemaugh River. Also shown on this map are wells and springs used as drinking water sources, as well as surface water and groundwater withdrawals used for agriculture and other industrial and municipal uses. Note that there are a number of private drinking water wells immediately downstream of the effluent outfall of PBT-Josephine Facility in close proximity to Blacklick Creek and more private drinking water wells further downstream after Blacklick Creek's convergence with a south flowing branch.

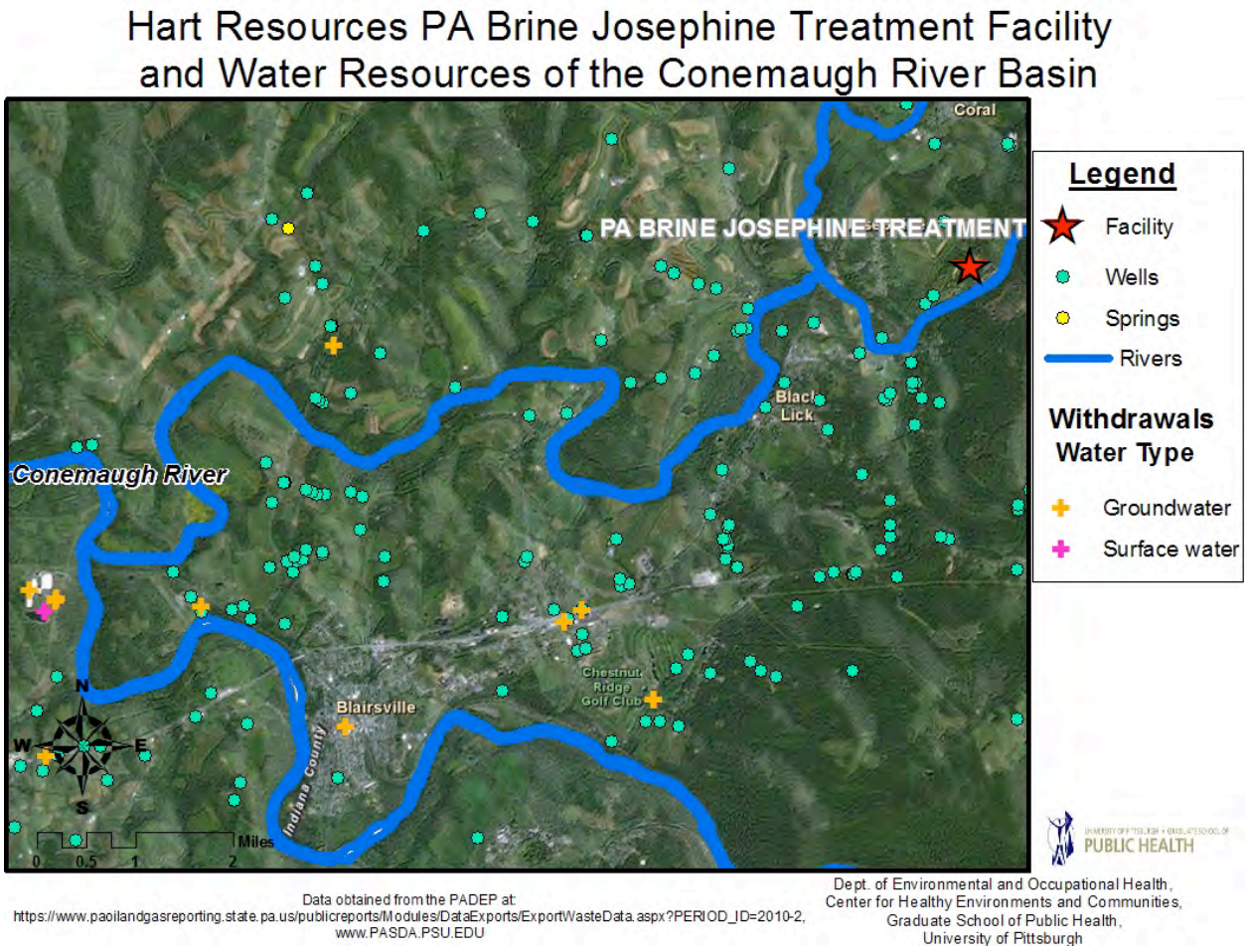

Figure 23. Focused Map of PBT-Josephine Facility on Blacklick Creek and Area Water Wells and Springs

Private well water users are at risk of exposure to contaminants in effluent being released into Blacklick Creek because these private wells may capture water from the creek when the well pump rate is sufficiently high (capture of surface water can occur when the well pump rate is greater than the product of the distance of the well from the stream times the aquifer thickness times the specific discharge of the aquifer times pi). High pump rates can occur especially during peak usage by residents. It is quite possible that 2-BE deposited in stream sediments will take appreciably longer to degrade than its range of 7-28 days in surface water, because aerobic degradation is the main transformation process for 2-BE degradation and the rate of aerobic transformation of 2-BE decreases with increasing depths of sediment (i.e., decreasing availability of oxygen) (ATSDR, 1998). Persistent 2-BE trapped in Blacklick stream sediments could be transported

to groundwater and ultimately private drinking water wells, located near Blacklick Creek.

With the passage of the Safe Drinking Water Act, the United States Environmental Protection Agency implemented the Wellhead Protection Program and the Source Water Assessment Program (USEPA, 1999).This program requires that source waters to a well or well field be identified, along with the capture zone of wells, and potential contaminant sources so that areas in the capture zone can be identified as wellhead protection areas. The SDWA does not apply to private drinking water wells, but contaminant transport to these wells should be evaluated to assure users that their water is safe to drink. Private well water from wells immediately downstream of the PBT-Josephine Facility and in close proximity to Blacklick Creek should be sampled and analyzed for priority contaminants found in PBT-Josephine Facility effluent. These wells should also be sampled for other contaminants of environmental public health importance that are in Marcellus Shale flowback and other oil and gas waste fluids. There are indications that downstream of this discharge point there are wells that may draw very large quantities of water for golf course irrigation and other uses, it is not known if any of these wells are used as drinking water sources.

Figure 24, Map of the Conemaugh River Basin and Wells and Springs in the Basin by Withdrawal Type, shows the location of all documented wells and springs used for drinking water and other uses in the basin, relative to all facilities accepting oil and gas wastewater/Marcellus Shale flowback water and natural gas solid waste. Water sources are further classified according to the type of source, groundwater or surface water. There are hundreds of private water wells downstream and proximal to streams and rivers that receive treated effluent from POTW's and treatment facilities accepting oil and gas wastewater and Marcellus Shale flowback water and potential runoff and leachate from landfills accepting natural gas waste solids.

Municipal water users are at less risk than recreationalists and Blacklick Creek private well water users of ingestion of identified contaminants in PBT-Josephine Facility effluent as contaminant levels will decrease with the distances downstream from the effluent outfall and the volumes of stream and river water available for dilution. However, there are numerous facilities accepting oil and gas waste-fluids and Marcellus Shale flowback water in the Conemaugh-

Kiskikiminetas-Allegheny River drainage. Figure 24, Map of the Conemaugh River Basin and Wells and Springs in the Basin by Withdrawal Type, shows four facilities that accept Marcellus Shale flowback water and oil and gas wastewater (Hart Resources Treatment, Whipstock Natural Gas Services, PBT-Josephine Facility and Johnstown POTW) as well as two facilities that accept solid waste from treatment facilities (Waste Management Evergreen Landfill and Laurel Highlands Landfill) in close proximity. Drainage and effluent from all of these facilities, except from Hart Resources Treatment flows into the Conemaugh-Kiskikiminetas drainage. The Hart Resources Treatment facility drainage flows into Crooked Creek. Both the Conemaugh-Kiskikiminetas system and the Crooked Creek system flow into the Allegheny River.

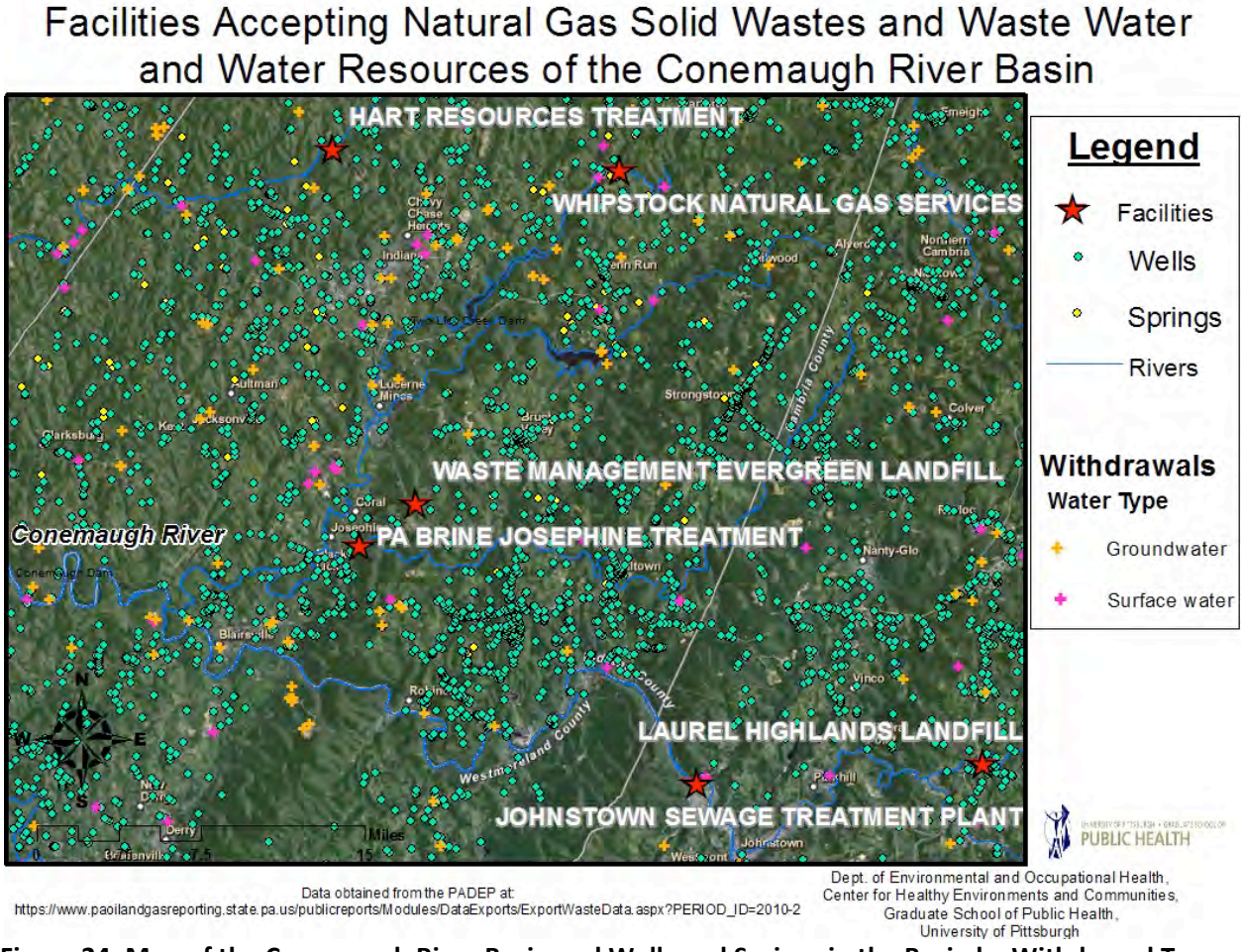

Figure 24. Map of the Conemaugh River Basin and Wells and Springs in the Basin by Withdrawal Type

The first identified municipal drinking water intake downstream of the PBT-Josephine discharge and other Marcellus Shale flowback fluid treatment discharges in the Conemaugh-Kiskikiminetas and Crooked Creek drainages is at Freeport, Pennsylvania on the Allegheny River. It is possible for 2-BE to be transported downstream by advective and fickian forces and remain in water primarily in the dissolved state with very little partitioning to suspended solids and sediment (ATSDR, 1998); and it could reach this intake as aerobic biodegradation appears to be the most important transformation process for 2-BE in water, with the biodegradation half-life of 2-BE in natural bodies of surface waters estimated to be in the range of 7-28 days (ATSDR, 1998). The intermediate products of aerobic biodegradation of 2-butoxyethanol have not been identified. Neither direct photolysis nor hydrolysis is an important transformation process for 2-BE in water (ATSDR, 1998).

Populations served by the Freeport authority and water authorities downstream of Freeport are at potential risk for exposure to contaminants identified in PBT-Josephine Facility effluent water. The PBT-Josephine results should inform regulatory agencies and water treatment plant operators that there could be multiple threats to water supplies from treatment facilities accepting Marcellus Shale flowback water and discharging effluent containing unidentified cations, anions, radionuclides and organic chemicals into surface water. Contaminants of concern can be predicted from published inventories of contaminants in Marcellus Shale flowback water (Hayes, 2009; Blauch et. al, 2009). Figure 25, Location of Public Water Supply (PWS) Stations in the Upper Ohio River Basin and Facilities that Discharge Treated Marcellus Shale Wastewater or Accept Natural Gas Solid Waste, shows PWS stations on the Allegheny River that should be made aware of the results and implications of this report, so that appropriate actions may be implemented. The Freeport PWS station is located at the junction of Armstrong, Butler and Allegheny Counties on the Allegheny River. There are seven (7) additional PWS stations between Freeport and the confluence of the Allegheny River with the Monongahela River, including the Pittsburgh Sewer and Water Authority (PSWA).

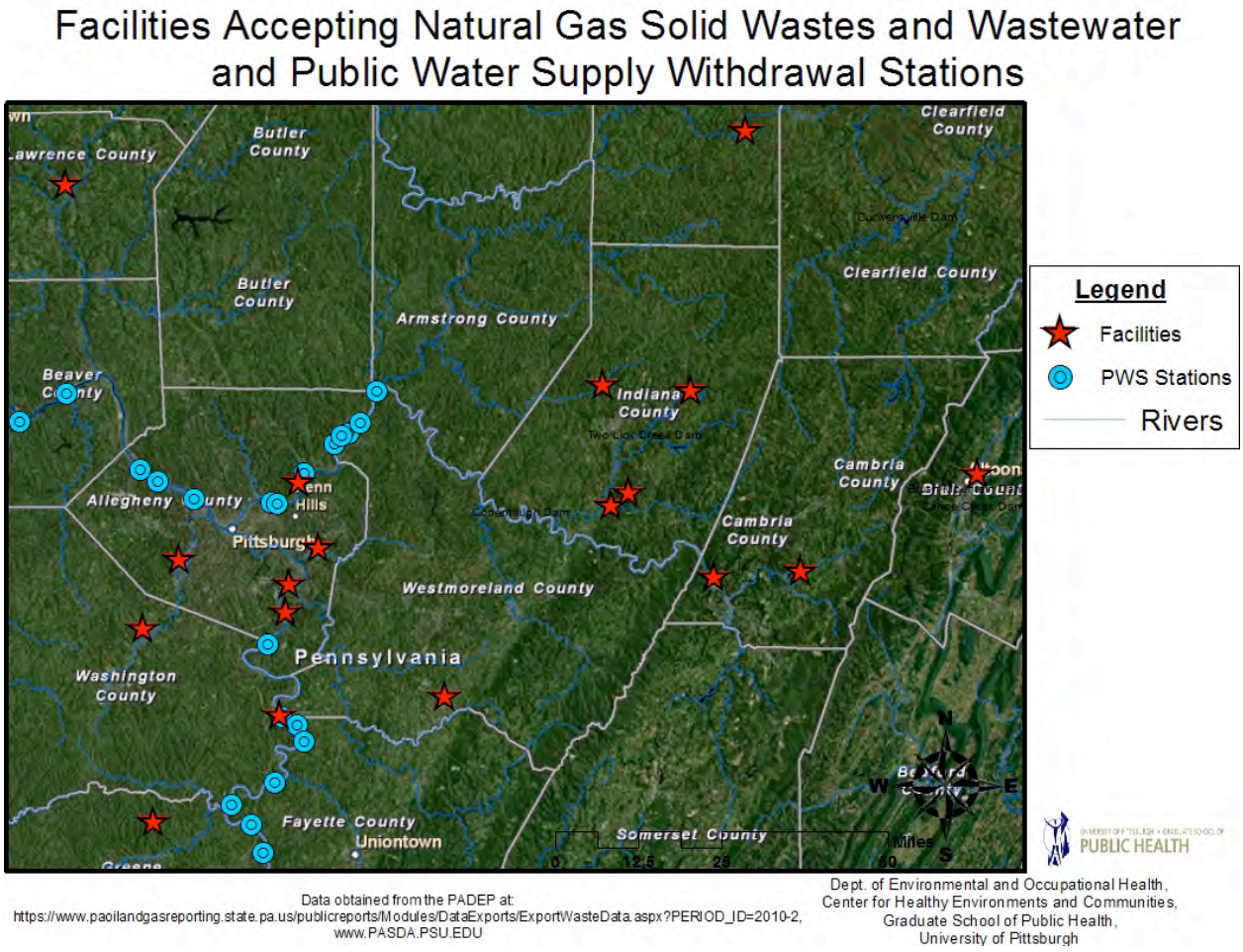

Figure 25. Location of Public Water Supply (PWS) Stations in the Upper Ohio River Basin and Facilities that Discharge Treated Marcellus Shale Wastewater or Accept Natural Gas Solid Waste

Implications of Effluent Discharge from the PBT – Josephine Facility for Exposures to Other Contaminants Known to be Present in Marcellus Shale Flowback Fluids and a Regional Appreciation of These Results

Of particular environmental public health significance is that Marcellus Shale flowback water contains other contaminants, in addition to those analyzed for in this study, which have health consequences if ingested, and/or inhaled, and/or absorbed through the skin. Exposure to these chemicals is dependant on their ability to be taken in through each route of entry, their concentration and their physical/chemical properties. These include other organic compounds including phenols and halogenated hydrocarbons, radionuclides including radioisotopes of radium, and other elements including lithium. While we make no statements regarding the presence of other contaminants in this effluent water being discharged into Blacklick Creek; it is imperative that additional work be done immediately by federal and state health and enforcement agencies to determine if other contaminants of public health significance are entering this and associated watersheds. Figures 23 and 24 show numerous private water wells in the Blacklick Creek and Conemaugh River drainages, which are downstream of POTW's and treatment facilities that are accepting oil and gas wastewater and Marcellus Shale flowback water.

Additionally, oil and gas wastewater and Marcellus shale flowback fluids are being disposed of in "brine treatment" facilities and at Publically Owned Treatment Works (POTW's) throughout the Commonwealth of Pennsylvania and in Ohio, West Virginia, and New York. We have been unable to find any published research evaluating contaminants or water quality variables in discharged effluent from POTW's or brine treatment plants accepting oil and gas wastewater/Marcellus Shale flowback or produced water and believe this is the first report of this type. Figure 25 shows that there are at least twenty (20) PWS stations in the upper Ohio River basin of southwestern Pennsylvania that are downstream of POTW's and/or brine treatment facilities, which accept oil and gas wastewater and Marcellus Shale flowback water and release wastewater effluent into receiving streams and rivers. Figure 26, Facilities Accepting Natural Gas Wastewater and Solids for Ultimate Treatment/Disposal in 6 State Area, shows facilities that are accepting natural gas wastewater including Marcellus Shale flowback fluids or solid waste from gas drilling operations and treatment facilities generated only in

Pennsylvania in the last half of 2010. The facilities on this map include POTW's, brine treatment facilities, solid waste facilities and Class II Injection wells.

Marcellus Shale and Utica Shale natural gas operations are ongoing in Ohio, Pennsylvania, and West Virginia and in vertical wells only in New York –the amounts of flowback water generated per any time period are unknown for wells in OH, WV and NY, as are the types and locations of facilities treating this liquid waste from those states. We were surprised to learn from the DEP data that flowback fluids from PA are being taken to NY and OH for treatment and subsequent surface water disposal. The ramifications of disposal of large quantities of oil and gas wastewater through ineffectual brine treatment plants and POTW's needs further evaluation throughout the region to determine its impact on stream and river systems and public drinking water supplies, as well as to recreationalists and private well water users.

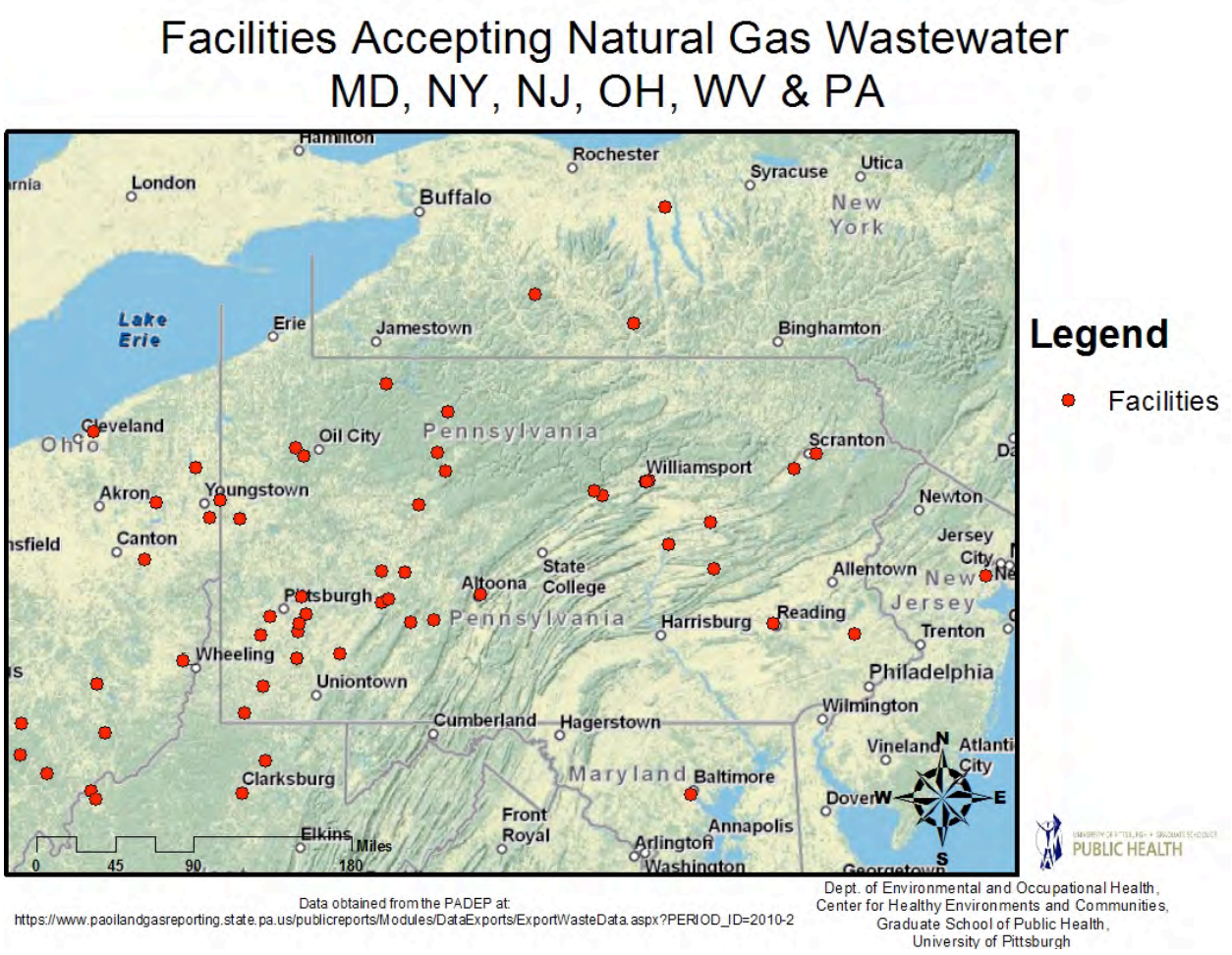

Figure 26. Facilities Accepting Natural Gas Wastewater and Solids for Ultimate Treatment/Disposal in 6 State Area[3]

Recommendations

- The Pennsylvania Brine Treatment – Josephine Facility is discharging up to 60 ppm of 2-BE into Blacklick Creek, which is not listed in its discharge permit. Operations at this plant should be halted until all contaminants in accepted oil and gas fluids are known and it can be determined if the treatment processes used at the plant effectively remove these

[3] To access a visualization of these disposal facilities, which can be manipulated and queried to find the disposal method, name and address of the facility, and amounts of sediment/brine/drill cuttings/ and frac fluids go to: http://data.fractracker.org/cbi/snapshot/page?concept=~012740e6964f0811e0bb12c54395733a3b# . This visualization is based on a dataset that is available from the PA DEP at https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/DataExports/ExportWasteData.aspx?PERIOD_ID=2010-2. The DEP dataset has been modified by pivoting the data to focus on the location accepting the waste rather than the well from which it was generated. The modified, pivoted dataset can be downloaded at: http://data.fractracker.org/cbi/dataset/datasetPreviewPage?uuid=~01bc2dae963ebf11e0ac208b3875ae825b.

contaminants from the fluids being treated, so that effluent discharge concentrations of contaminants are consistent with human and aquatic health standards, guidelines and criteria.

- All approaches to the effluent discharge area and a reasonable distance downstream (at least 100 meters) from stream-side and land-side should be posted with warning signs. These signs should discourage any use of and/or contact with stream water.
- An advisory should be issued to all anglers that fish taken from this stream, both up and down stream, may be contaminated and discouraging fish take and of course consumption.
- Studies to determine the levels of all potential Marcellus Shale flowback fluid contaminants in downstream water, sediments and pore water should be undertaken immediately. These should include sampling upstream of the effluent discharge point and at short, intermediate and longer distances downstream from the effluent discharge point. The number of samples taken (n) of surface water, sediments and pore water upstream and at the various distances downstream should be sufficient so that statistically significant differences of contaminant concentrations can be inferred.
- Residential and other private well water users downstream of the effluent outfall of the PBT-Josephine Facility should be advised that there may be contaminants in their well water and discouraged from using it for drinking, cooking or bathing. Well water from wells in close proximity to Blacklick Creek should be tested to assure that contaminants in Marcellus Shale flowback fluids and other oil and gas waste fluids are not present in concentrations that may affect human health.
- Municipal water authorities downstream of this outfall should be notified of the contaminants found in effluent from the PBT- Josephine Facility, of other possible contaminants in Marcellus Shale flowback fluids and oil and gas wastewater, and that there are other treatment facilities and POTW's in the Blacklick, Conemaugh, and Kiskiminetas drainages that accept and discharge oil and gas waste fluids into surface water. They should also be notified that landfill facilities in the drainage accept solid wastes produced from these treatment facilities. Downstream municipal water authorities should test raw unfinished intake water and finished drinking water for identified contaminants in effluent from the PBT- Josephine Facility, and other contaminants known to be present in Marcellus Shale flowback fluids and oil and gas wastewater.

- All municipal water authorities at reasonable distances downstream of "brine treatment" and POTW's accepting Marcellus Shale flowback fluids and other oil and gas wastewater in the region extending eastward across Ohio, Pennsylvania and West Virginia and New York should be notified of these results. It is important that they initiate sampling of raw, unfinished inflow water and finished drinking water immediately to insure that their systems are capable of handling all potential contaminants, without breakthrough above specific drinking water MCL's.
- The PA DEP and other states and federal regulatory authorities should immediately review all surface water discharge permits granted to brine treatment facilities and POTW's that accept Marcellus Shale flowback fluids and oil and gas wastewater, to insure that 2-BE concentrations being discharged are below all applicable standard, guidelines and criteria. This review should be informed by results of this report but should be extended to all known contaminants in flowback and other oil and gas wastewater.

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Appendix A

Pennsylvania PBT Brine Treatment

PENNSYLVANIA BRINE TREATMENT

5148 US 322 • FRANKLIN, PA 16323 • 814-437-3593 • FAX 814-432-3047

January 25, 2011

Alan Eichler
Department of Environmental Protection
Oil and Gas Management
400 Waterfront Drive
Pittsburgh, PA 15222-4745

SUBJECT: December 2010 - Discharge Monitoring Report
Pennsylvania Brine Treatment - Josephine Plant

Dear Mr. Eichler:

During the month of December, we processed and discharged a total of 3,237,387 gallons as follows:

December 1	154,820
December 2	154,920
December 3	154,430
December 4	155,000
December 5	17,000
December 6	102,430
December 7	21,732
December 8	117,895
December 9	153,725
December 10	152,545
December 11	31,579
December 12	85,374
December 13	136,720
December 14	33,517
December 15	142,466
December 16	154,680
December 17	151,740
December 18	108,800
December 19	37,779
December 20	17,887
December 21	154,593
December 22	154,752

December 23	155,000
December 24	112,292
December 25	0
December 26	94,450
December 27	140,900
December 28	44,566
December 29	154,170
December 30	135,285
December 31	6,340

The enclosed report is a summary of the results of analyses tested as required by our permit.

If you have any questions or comments regarding the results of our current operation, please do not hesitate to contact us.

Sincerely,

PENNSYLVANIA BRINE TREATMENT

Elton W. DeLong

Elton W. DeLong, Jr.
Operations Manager

EWD/th

Enclosures

cc: Kristin Gearhart,
Water Quality Specialist
Cambria Office
Bureau of Water Quality Management
286 Industrial Park Road
Ebensburg, PA 15931-4119

PENNSYLVANIA BRINE TREATMENT, INC.

ATLAS RESOURCES, INC.

101 McQuiston Drive, Jackson Center, PA 16133

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
01-Dec-10	9120	98132	JOS	WSI	Shallenberger #2-22293	J-Brine	1386	33
01-Dec-10	9120	98132	JOS	WSI	Shallenberger #1-22292	J-Brine	2814	67
01-Dec-10	9125	98137	JOS	HAR	Elias #12H-25716 (M)	J-Mar-Frac	4620	110
01-Dec-10	9126	98138	JOS	BUR	Doney #11-23942 (M)	J-Mar-Brine	4620	110
01-Dec-10	9129	98141	JOS	HAR	Elias #12H-25716 (M)	J-Mar-Frac	4200	100
01-Dec-10	9131	98143	JOS	HAR	Elias #12H-25716 (M)	J-Mar-Frac	4200	100
01-Dec-10	9132	98144	JOS	HAR	Elias #12H-25716 (M)	J-Mar-Frac	4200	100
01-Dec-10	9134	98146	JOS	BUR	Orr #36-23887 (M)	J-Mar-Brine	3990	95
01-Dec-10	9135	98147	JOS	BUR	Layman #6-24189 (M)	J-Mar-Brine	3990	95
01-Dec-10	9138	98150	JOS	DII	Buday #7-21333	J-Brine	2142	51
01-Dec-10	9138	98150	JOS	DII	Buday #5-21331	J-Brine	1050	25
01-Dec-10	9140	98152	JOS	WSI	Yeagley #1-24507 (M)	J-Mar-Brine	4200	100
01-Dec-10	9146	98158	JOS	HAR	Elias #12H-25716 (M)	J-Mar-Frac	4620	110
01-Dec-10	9147	98159	JOS	BUR	Olexa #8-23979 (M)	J-Mar-Brine	4620	110
01-Dec-10	9151	98163	JOS	BUR	Greenawalt #23-24496 (M)	J-Mar-Brine	4284	102
01-Dec-10	9156	98168	JOS	DII	Buday #2-20974	J-Brine	2100	50
01-Dec-10	9156	98168	JOS	DII	Whipkey #5-21564	J-Brine	2100	50
01-Dec-10	9157	98169	JOS	BUR	Lash #17-23653 (M)	J-Mar-Brine	4704	112
01-Dec-10	9159	98171	JOS	BUR	Babich #3-23938 (M)	J-Mar-Brine	4620	110
01-Dec-10	9162	98172	JOS	KMI	Elias #11H-25715 (M)	J-Mar-Frac	5040	120
01-Dec-10	10262	154533	FKL	BUR	Hunter Unit #24-24360 (M)	F-Mar-Brine	4620	110
01-Dec-10	10293	154569	FKL	BUR	Winger #1H-18074 (M)	REJECTED	0	0
01-Dec-10	10294	154568	FKL	BUR	Winger #1H-18074 (M)	REJECTED	0	0
01-Dec-10	10295	154570	FKL	BUR	Winger #1H-18074 (M)	REJECTED	0	0
01-Dec-10	19510	154584	FKL	BUR	Smouse #5-24557 (M)	F-Mar-Brine	4620	110
02-Dec-10	9160	98173	JOS	BUR	Baughman #1-22971 (M)	J-Mar-Brine	4620	110
02-Dec-10	9163	98175	JOS	BUR	Serro #8-25304 (M)	J-Mar-Brine	4200	100
02-Dec-10	9165	98177	JOS	BUR	Hunter #11-22460 (M)	J-Mar-Brine	4326	103
02-Dec-10	9167	98179	JOS	WPK	Huczko #2-30418 (M)	J-Mar-Brine	4166	99
02-Dec-10	9169	98181	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
02-Dec-10	9171	98183	JOS	WSI	Clarke #14-22831 (M)	J-Mar-Brine	4200	100
02-Dec-10	9173	98185	JOS	HAR	Smith #39-23467 (M)	J-Mar-Frac	3570	85
02-Dec-10	9175	98187	JOS	BUR	Redman #30-25027 (M)	J-Mar-Brine	4620	110
02-Dec-10	9176	98188	JOS	BUR	Redman #29-25026 (M)	J-Mar-Brine	4620	110
02-Dec-10	9177	98189	JOS	BUR	Huber #13-22968 (M)	J-Mar-Brine	4200	100
02-Dec-10	9178	98190	JOS	BUR	Huber #14-23647 (M)	J-Mar-Brine	4200	100
02-Dec-10	9189	98201	JOS	BUR	Hosler #7-24035 (M)	J-Mar-Brine	4200	100
02-Dec-10	9191	98203	JOS	WSI	Olbrys #1-20903	J-Brine	2100	50
02-Dec-10	9191	98203	JOS	WSI	Pradella #2-16870	J-Brine	1596	38

02-Dec-10	9194	98206	JOS	BUR	Doney #13-23944 (M)	J-Mar-Brine	4620	110
02-Dec-10	19576	154651	FKL	BUR	Hunter #13-22462 (M)	F-Mar-Brine	4620	110
02-Dec-10	19577	154653	FKL	BUR	Fulmer #11-21956 (M)	F-Mar-Brine	4200	100
02-Dec-10	19578	154654	FKL	BUR	Olexa #9-24036 (M)	F-Mar-Brine	3822	91
02-Dec-10	19579	154657	FKL	KMI	Colvin #6-26018 (M)	F-Mar-Frac	4620	110
02-Dec-10	19580	154658	FKL	KMI	Colvin #6-26018 (M)	F-Mar-Frac	5460	130
02-Dec-10	19581	154660	FKL	KMI	Colvin #6-26018 (M)	F-Mar-Frac	5040	120
02-Dec-10	19582	154659	FKL	KMI	Colvin #6-26018 (M)	F-Mar-Frac	4620	110
03-Dec-10	9195	98207	JOS	BUR	Phillips #21-24175 (M)	J-Mar-Brine	4620	110
03-Dec-10	9198	98210	JOS	WPK	McGrath Unit #1-30425 (M)	J-Mar-Brine	4166	99
03-Dec-10	9199	98211	JOS	WSI	Yeagley #1-24507 (M)	J-Mar-Brine	4200	100
03-Dec-10	9210	98222	JOS	BUR	Yates #3-24177 (M)	J-Mar-Brine	4620	110
03-Dec-10	9211	98223	JOS	DII	Check #1-192290	J-Brine	1260	30
03-Dec-10	9211	98223	JOS	DII	Vail #3-16462	J-Brine	2520	60
03-Dec-10	9224	98236	JOS	WSI	Wivell #1-16044	J-Brine	1512	36
03-Dec-10	9224	98236	JOS	WSI	Sobek #1-20582	J-Brine	2688	64
03-Dec-10	9225	98237	JOS	BUR	Babich #3-23938 (M)	J-Mar-Brine	4200	100
03-Dec-10	10309	154683	FKL	BUR	Phillips #20-24174 (M)	F-Mar-Brine	3906	93
03-Dec-10	10328	154688	FKL	BUR	Doney #12-23943 (M)	F-Mar-Brine	4158	99
03-Dec-10	10438	154729	FKL	BUR	Burnside #8-21729 (M)	F-Mar-Brine	3780	90
04-Dec-10	9230	98242	JOS	DII	Honsaker #17-24494 (M)	J-Mar-Brine	3780	90
06-Dec-10	414	154825	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5460	130
06-Dec-10	9232	98244	JOS	WPK	McGrath Unit #1-30425 (M)	J-Mar-Brine	4166	99
06-Dec-10	9237	98249	JOS	DII	Burchianti #11A-22705 (M)	J-Mar-Brine	3780	90
06-Dec-10	9238	98250	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
06-Dec-10	9243	98255	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
06-Dec-10	9248	98260	JOS	WPK	Rau Unit #2H-25742 (M)	J-Mar-Brine	4166	99
06-Dec-10	9255	98267	JOS	BUR	Kisner #6-24269 (M)	J-Mar-Brine	4200	100
06-Dec-10	9257	98269	JOS	BUR	Angelcyk #7-23704 (M)	J-Mar-Brine	4620	110
06-Dec-10	10346	154787	FKL	BUR	Serro #8-25304 (M)	F-Mar-Brine	4620	110
06-Dec-10	10349	154791	FKL	BUR	Redman #29-25026 (M)	F-Mar-Brine	4200	100
06-Dec-10	10387	154822	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4620	110
06-Dec-10	10388	154823	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4620	110
06-Dec-10	10389	154824	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4830	115
06-Dec-10	10390	154826	FKL	KMI	National Mines #26H-25924 (M)	F-Mar-Frac	5040	120
06-Dec-10	10391	154827	FKL	KMI	National Mines #26H-25924 (M)	F-Mar-Frac	5460	130
06-Dec-10	10392	154829	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4200	100
07-Dec-10	9258	98270	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
07-Dec-10	9260	98272	JOS	DII	McClain #1-21062	J-Brine	3780	90
07-Dec-10	9261	98273	JOS	BUR	Matty/Momyer #1-25650 (M)	J-Mar-Brine	4032	96
07-Dec-10	9262	98274	JOS	BUR	Plassio #2-22198 (M)	J-Mar-Brine	1050	25
07-Dec-10	9262	98274	JOS	BUR	Plassio #3-22281 (M)	J-Mar-Brine	1050	25
07-Dec-10	9262	98274	JOS	BUR	Plassio #1-22280 (M)	J-Mar-Brine	1260	30
07-Dec-10	9262	98274	JOS	BUR	Bazzo #1-23418	J-Brine	1260	30
07-Dec-10	9264	98276	JOS	WPK	Rau Unit #2H-25742 (M)	J-Mar-Brine	4166	99
07-Dec-10	9272	98284	JOS	DII	Rozak #4-22899	J-Brine	1470	35
07-Dec-10	9272	98284	JOS	DII	Rozak #2-22897	J-Brine	2730	65

07-Dec-10	9275	98288	JOS	BUR	Lash #16-23652 (M)	J-Mar-Brine	3780	90
07-Dec-10	9279	98291	JOS	BUR	Phillips #21-24175 (M)	J-Mar-Brine	4620	110
08-Dec-10	9283	98295	JOS	BUR	Phillips #20-24174 (M)	J-Mar-Brine	4200	100
08-Dec-10	9284	98296	JOS	WSI	Clarke #14-22831 (M)	J-Mar-Brine	4200	100
08-Dec-10	9288	98300	JOS	BUR	Serro #8-25304 (M)	J-Mar-Brine	4620	110
08-Dec-10	9295	98307	JOS	BUR	Hunter Unit #24-24360 (M)	J-Mar-Brine	3780	90
08-Dec-10	9304	98316	JOS	BUR	Olexa #9-24036 (M)	J-Mar-Brine	4200	100
08-Dec-10	9306	98318	JOS	BUR	Campbell #14-24157 (M)	J-Mar-Brine	4200	100
08-Dec-10	9310	98322	JOS	DII	Mislan #1-22236	J-Brine	1050	25
08-Dec-10	9310	98322	JOS	DII	Davis #8-22225	J-Brine	966	23
08-Dec-10	9310	98322	JOS	DII	Hice #4-22234	J-Brine	1050	25
08-Dec-10	9312	98324	JOS	BUR	Babich #3-23938 (M)	J-Mar-Brine	3906	93
08-Dec-10	9313	98325	JOS	WSI	Yeagley #1-24507 (M)	J-Mar-Brine	4200	100
08-Dec-10	9321	98333	JOS	BUR	Layman #6-24189 (M)	J-Mar-Brine	4200	100
08-Dec-10	9322	98334	JOS	BUR	Shoaf #8-23700 (M)	J-Mar-Brine	4620	110
08-Dec-10	9323	98335	JOS	WSI	Kepple #4-25106 (M)	J-Mar-Brine	4200	100
08-Dec-10	9324	98336	JOS	BUR	Doney #13-23944 (M)	J-Mar-Brine	3780	90
08-Dec-10	10560	154913	FKL	BUR	Lynn #9-25758 (M)	F-Mar-Brine	4620	110
08-Dec-10	10580	154954	FKL	BUR	Campbell #15-24302 (M)	F-Mar-Brine	4620	110
09-Dec-10	9326	98338	JOS	DII	Grimm #19-22228	J-Brine	2520	60
09-Dec-10	9326	98338	JOS	DII	Grimm #20-22682	J-Brine	1260	30
09-Dec-10	9328	98340	JOS	WPK	McGrath Unit #1-30425 (M)	J-Mar-Brine	4166	99
09-Dec-10	9332	98344	JOS	WSI	Clarke #14-22831 (M)	J-Mar-Brine	4200	100
09-Dec-10	9334	98346	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
09-Dec-10	9338	98350	JOS	BUR	Huber #5-21657	J-Brine	2520	60
09-Dec-10	9338	98350	JOS	BUR	Huber #4-21656	J-Brine	2100	50
09-Dec-10	9342	98354	JOS	BUR	Shoaf #4-21652	J-Brine	1890	45
09-Dec-10	9342	98354	JOS	BUR	Shoaf #5-21653	J-Brine	1764	42
09-Dec-10	9342	98354	JOS	BUR	Shychuk #1-21681	J-Brine	882	21
09-Dec-10	9343	98355	JOS	BUR	Smouse #5-24557 (M)	J-Mar-Brine	3990	95
09-Dec-10	9348	98358	JOS	WSI	Lenz #1-20046	J-Brine	1218	29
09-Dec-10	9348	98358	JOS	WSI	Patrick #2A-20036	J-Brine	2982	71
09-Dec-10	9352	98364	JOS	DII	Springer #6-22145	J-Brine	3360	80
09-Dec-10	9352	98364	JOS	DII	Honsaker #1-23396	J-Brine	840	20
09-Dec-10	9356	98368	JOS	BUR	Redman #29-25026 (M)	J-Mar-Brine	4620	110
09-Dec-10	9361	98373	JOS	BUR	Hammel Unit #2-25528 (M)	J-Mar-Brine	2100	50
09-Dec-10	9361	98373	JOS	BUR	Stopka #1-23161	J-Brine	1932	46
09-Dec-10	9361	98373	JOS	BUR	Stopka #4-23164	J-Brine	588	14
09-Dec-10	9362	98374	JOS	BUR	Olexa #8-23979 (M)	J-Mar-Brine	4620	110
09-Dec-10	9364	98376	JOS	BUR	Brazzon #7-24301 (M)	J-Mar-Brine	4410	105
10-Dec-10	9366	98378	JOS	BUR	Hosler #8-24695 (M)	J-Mar-Brine	4200	100
10-Dec-10	9367	98379	JOS	BUR	Burnside #8-21729 (M)	J-Mar-Brine	4620	110
10-Dec-10	9368	98380	JOS	BUR	Orr #33-21231 (M)	J-Mar-Brine	4620	110
10-Dec-10	9371	98383	JOS	BUR	Orr #36-23887 (M)	J-Mar-Brine	4620	110
10-Dec-10	9372	98384	JOS	BUR	Angelcyk #6-23649 (M)	J-Mar-Brine	4200	100
10-Dec-10	9376	98388	JOS	WSI	Halvorsen #1-22906	J-Brine	2520	60
10-Dec-10	9376	98388	JOS	WSI	Paul #6-23287	J-Brine	1680	40

10-Dec-10	9377	98389	JOS	BUR	Baughman #1-22971 (M)	J-Mar-Brine	3780	90
10-Dec-10	9379	98391	JOS	WPK	Huczko #2-30418 (M)	J-Mar-Brine	4166	99
10-Dec-10	9383	98395	JOS	DII	Honsaker #1-23396	J-Brine	1050	25
10-Dec-10	9383	98395	JOS	DII	Honsaker #5-23400	J-Brine	2730	65
10-Dec-10	9385	98397	JOS	BUR	Fulmer #11-21956 (M)	J-Mar-Brine	4200	100
10-Dec-10	9392	98404	JOS	WSI	Frenchek #1-20629	J-Brine	1176	28
10-Dec-10	9392	98404	JOS	WSI	Kepple #4-25106 (M)	J-Mar-Brine	3024	72
10-Dec-10	9394	98406	JOS	BUR	Shychuk #7-24756 (M)	J-Mar-Brine	4452	106
10-Dec-10	9396	98408	JOS	DII	Biddle #1-16485	J-Brine	1680	40
10-Dec-10	9396	98408	JOS	DII	Biddle #6-21471	J-Brine	1260	30
10-Dec-10	9396	98408	JOS	DII	Biddle #15-22059	J-Brine	1260	30
10-Dec-10	9398	98410	JOS	BUR	Hunter Unit #24-24360 (M)	J-Mar-Brine	4200	100
10-Dec-10	9402	98414	JOS	BUR	Babich #3-23938 (M)	J-Mar-Brine	4200	100
12-Dec-10	9403	98415	JOS	WSI	Usher #1-21433	J-Brine	1722	41
12-Dec-10	9403	98415	JOS	WSI	Coldren #1-20580	J-Brine	1428	34
12-Dec-10	9403	98415	JOS	WSI	Behanna #3-20628	J-Brine	1050	25
13-Dec-10	9407	98419	JOS	WPK	McGrath Unit #1-30425 (M)	J-Mar-Brine	4166	99
13-Dec-10	9412	98424	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
13-Dec-10	9415	98427	JOS	DII	Burchianti #18-22748	J-Brine	1176	28
13-Dec-10	9415	98427	JOS	DII	Kemerer #2-16892	J-Brine	2604	62
13-Dec-10	9418	98430	JOS	BUR	Serro #8-25304 (M)	J-Mar-Brine	3780	90
13-Dec-10	9419	98431	JOS	WPK	Rau Unit #2H-25742 (M)	J-Mar-Brine	4166	99
13-Dec-10	9420	98432	JOS	WSI	Clarke #14-22831 (M)	J-Mar-Brine	4200	100
13-Dec-10	9427	98439	JOS	BUR	Kisner #6-24269 (M)	J-Mar-Brine	3990	95
13-Dec-10	9428	98440	JOS	BUR	Hosler #7-24035 (M)	J-Mar-Brine	3780	90
13-Dec-10	10686	155177	FKL	BUR	Doney #12-23943 (M)	F-Mar-Brine	4620	110
13-Dec-10	10758	155134	FKL	BUR	Redman #30-25027 (M)	F-Mar-Brine	4620	110
13-Dec-10	10763	155142	FKL	BUR	Redman #29-25026 (M)	F-Mar-Brine	4200	100
14-Dec-10	9433	98445	JOS	WSI	Yeagley #1-24507 (M)	J-Mar-Brine	4200	100
14-Dec-10	9440	98452	JOS	DII	Pritts #3-25197 (M)	J-Mar-Brine	4200	100
14-Dec-10	9442	98454	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
14-Dec-10	9446	98458	JOS	BUR	Olexa #9-24036 (M)	J-Mar-Brine	3990	95
14-Dec-10	9447	98459	JOS	DEV	Pritts #3-25197 (M)	J-Mar-Brine	4200	100
14-Dec-10	9448	98460	JOS	BUR	Serro #8-25304 (M)	J-Mar-Brine	4620	110
14-Dec-10	9450	98462	JOS	WSI	Yeagley #1-24507 (M)	J-Mar-Brine	4200	100
14-Dec-10	9451	98463	JOS	WPK	Rau Unit #2H-25742 (M)	J-Mar-Brine	4166	99
14-Dec-10	9452	98464	JOS	BUR	Yost #4-21142	J-Brine	2310	55
14-Dec-10	9452	98464	JOS	BUR	Yost #11-22027	J-Brine	2310	55
14-Dec-10	9455	98467	JOS	DII	Pritts #3-25197 (M)	J-Mar-Brine	3150	75
14-Dec-10	9457	98469	JOS	BUR	Phillips #20-24174 (M)	J-Mar-Brine	4200	100
14-Dec-10	9458	98470	JOS	BUR	Shoaf #7-23651 (M)	J-Mar-Brine	4620	110
14-Dec-10	9463	98475	JOS	BUR	Babich #3-23938 (M)	J-Mar-Brine	3360	80
14-Dec-10	9464	98476	JOS	BUR	Lash #16-23652 (M)	J-Mar-Brine	4620	110
14-Dec-10	9465	98477	JOS	BUR	Hunter Unit #24-24360 (M)	J-Mar-Brine	4620	110
15-Dec-10	418	155328	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5460	130
15-Dec-10	9466	98478	JOS	BUR	Orr #36-23887 (M)	J-Mar-Brine	4074	97
15-Dec-10	9467	98479	JOS	WPK	McGrath Unit #1-30425 (M)	J-Mar-Brine	4166	99

15-Dec-10	9468	98480	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	5460	130
15-Dec-10	9469	98481	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	5040	120
15-Dec-10	9470	98482	JOS	WSI	Yeagley #1-24507 (M)	J-Mar-Brine	4200	100
15-Dec-10	9473	98485	JOS	BUR	Orr #33-21231 (M)	J-Mar-Brine	4620	110
15-Dec-10	9476	98488	JOS	DII	Porupski #3-21494	J-Brine	3150	75
15-Dec-10	9477	98489	JOS	HAR	Pritts #3-25197 (M)	J-Mar-Frac	4620	110
15-Dec-10	9478	98490	JOS	HAR	Pritts #3-25197 (M)	J-Mar-Frac	3570	85
15-Dec-10	9479	98491	JOS	HAR	Pritts #3-25197 (M)	J-Mar-Frac	3570	85
15-Dec-10	9480	98492	JOS	HAR	Pritts #3-25197 (M)	J-Mar-Frac	3570	85
15-Dec-10	9481	98493	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4830	115
15-Dec-10	9482	98494	JOS	HAR	Pritts #3-25197 (M)	J-Mar-Frac	4200	100
15-Dec-10	9483	98495	JOS	WPK	Huczko #2-30418 (M)	J-Mar-Brine	4166	99
15-Dec-10	9484	98496	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	5020	120
15-Dec-10	9485	98497	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	5460	130
15-Dec-10	9486	98498	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4200	100
15-Dec-10	9488	98500	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4830	115
15-Dec-10	9490	98502	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4830	115
15-Dec-10	9491	98503	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4200	100
15-Dec-10	9492	98504	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	5040	120
15-Dec-10	9493	98505	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4620	110
15-Dec-10	9494	98506	JOS	BUR	Olexa #8-23979 (M)	J-Mar-Brine	4074	97
15-Dec-10	9496	98509	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	5040	120
15-Dec-10	9497	98508	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	5460	130
15-Dec-10	9499	98511	JOS	BUR	Shoaf #8-23700 (M)	J-Mar-Brine	4620	110
15-Dec-10	9503	98515	JOS	HAR	Pritts #3-25197 (M)	J-Mar-Frac	4200	100
15-Dec-10	9505	98517	JOS	HAR	Pritts #3-25197 (M)	J-Mar-Frac	3570	85
15-Dec-10	9506	98518	JOS	HAR	Pritts #3-25197 (M)	J-Mar-Frac	4200	100
15-Dec-10	9507	98519	JOS	DII	Langley #6-16819	J-Brine	1470	35
15-Dec-10	9507	98519	JOS	DII	Lilley #1-16729	J-Brine	1470	35
15-Dec-10	9507	98519	JOS	DII	Langley #4-20131	J-Brine	840	20
15-Dec-10	9509	98521	JOS	BUR	Smouse #5-24557 (M)	J-Mar-Brine	4200	100
15-Dec-10	9511	98523	JOS	BUR	Lash #17-23653 (M)	J-Mar-Brine	4620	110
15-Dec-10	15631	155299	FKL	BUR	Layman #6-24189 (M)	F-Mar-Brine	3780	90
15-Dec-10	15632	155301	FKL	BUR	Matty/Momyer #1-25650 (M)	F-Mar-Brine	4200	100
15-Dec-10	15649	155326	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5040	120
15-Dec-10	15650	155327	FKL	BUR	Greenawalt #23-24496 (M)	F-Mar-Brine	4620	110
15-Dec-10	15651	155329	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5040	120
15-Dec-10	15652	155330	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4620	110
15-Dec-10	15653	155331	FKL	BUR	Yates #3-24177 (M)	F-Mar-Brine	4200	100
15-Dec-10	15654	155332	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4830	115
15-Dec-10	15655	155334	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4620	110
16-Dec-10	419	155429	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5460	130
16-Dec-10	9516	98528	JOS	BUR	Redman #29-25026 (M)	J-Mar-Brine	4620	110
16-Dec-10	9517	98529	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
16-Dec-10	9519	98532	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	5460	130
16-Dec-10	9520	98531	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4620	110
16-Dec-10	9521	98533	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4200	100

16-Dec-10	9522	98534	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4830	115
16-Dec-10	9523	98535	JOS	WSI	Clarke #14-22831 (M)	J-Mar-Brine	4200	100
16-Dec-10	9525	98537	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4830	115
16-Dec-10	9526	98538	JOS	DII	Rich Farms #3-21041	J-Brine	2520	60
16-Dec-10	9526	98538	JOS	DII	Rich Farms #2-21166	J-Brine	1260	30
16-Dec-10	9532	98544	JOS	WSI	Kepple #4-25106 (M)	J-Mar-Brine	4200	100
16-Dec-10	9533	98545	JOS	BUR	Orr #33-21231 (M)	J-Mar-Brine	4620	110
16-Dec-10	9535	98547	JOS	DII	Benninger #24-22666 (M)	J-Mar-Brine	4200	100
16-Dec-10	9538	98550	JOS	BUR	Huber #13-22968 (M)	J-Mar-Brine	4620	110
16-Dec-10	15662	155342	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4200	100
16-Dec-10	15701	155422	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4620	110
16-Dec-10	15702	155423	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5040	120
16-Dec-10	15704	155425	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5460	130
16-Dec-10	15705	155426	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5040	120
16-Dec-10	15706	155427	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4830	115
16-Dec-10	15707	155428	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4620	110
16-Dec-10	15708	155430	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5040	120
16-Dec-10	15709	155432	FKL	BUR	Malik #4-22699 (M)	F-Mar-Brine	4410	105
16-Dec-10	15710	155433	FKL	BUR	Phillips #21-24175 (M)	F-Mar-Brine	4200	100
16-Dec-10	19476	155388	FKL	BUR	Campbell #15-24302 (M)	F-Mar-Brine	4200	100
16-Dec-10	19477	155389	FKL	BUR	Lynn #9-25758 (M)	F-Mar-Brine	4200	100
17-Dec-10	9543	98555	JOS	BUR	Hosler #8-24695 (M)	J-Mar-Brine	4620	110
17-Dec-10	9545	98557	JOS	BUR	Kisner #6-24269 (M)	J-Mar-Brine	4200	100
17-Dec-10	9548	98560	JOS	DII	Zinn #2-22153 (M)	J-Mar-Brine	3192	76
17-Dec-10	9553	98565	JOS	BUR	Burnside #8-21729 (M)	J-Mar-Brine	4620	110
17-Dec-10	9554	98566	JOS	DII	Dancho/Brown #5-24691 (M)	J-Mar-Brine	4200	100
17-Dec-10	9555	98567	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4830	115
17-Dec-10	9556	98568	JOS	BUR	Orr #33-21231 (M)	J-Mar-Brine	4200	100
17-Dec-10	9560	98572	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4830	115
17-Dec-10	9561	98573	JOS	BUR	Fulmer #11-21956 (M)	J-Mar-Brine	4620	110
17-Dec-10	9563	98575	JOS	BUR	Orr #33-21231 (M)	J-Mar-Brine	4578	109
17-Dec-10	15718	155442	FKL	BUR	Babich #3-23938 (M)	F-Mar-Brine	4200	100
17-Dec-10	15719	155443	FKL	BUR	Smouse #5-24557 (M)	F-Mar-Brine	4200	100
17-Dec-10	15799	155482	FKL	BUR	Doney #13-23944 (M)	F-Mar-Brine	4200	100
17-Dec-10	15800	155481	FKL	BUR	Campbell #14-24157 (M)	F-Mar-Brine	3990	95
17-Dec-10	15839	155504	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5460	130
17-Dec-10	15840	155505	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4620	110
17-Dec-10	15841	155506	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5040	120
17-Dec-10	15843	155509	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4620	110
17-Dec-10	15846	155514	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5460	130
18-Dec-10	9565	98577	JOS	DII	PRAH #2A-24083 (M)	J-Mar-Brine	3486	83
18-Dec-10	15901	155553	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	5460	130
18-Dec-10	15902	155554	FKL	KMI	Pritts #3-25197 (M)	F-Mar-Frac	4830	115
20-Dec-10	9570	98582	JOS	WPK	McGrath Unit #1-30425 (M)	J-Mar-Brine	4166	99
20-Dec-10	9571	98583	JOS	DII	Fay-Penn #44-24267 (M)□ (M)	J-Mar-Brine	4200	100
20-Dec-10	9572	98584	JOS	BUR	Redman #29-25026 (M)	J-Mar-Brine	4620	110
20-Dec-10	9573	98585	JOS	BUR	Redman #30-25027 (M)	J-Mar-Brine	4200	100

20-Dec-10	9576	98588	JOS	DII	Pevarnik #9-23384 (M)	J-Mar-Brine	2982	71
20-Dec-10	9578	98590	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	5040	120
20-Dec-10	9579	98591	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	4200	100
20-Dec-10	9582	98594	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
20-Dec-10	9589	98601	JOS	KMI	Pritts #3-25197 (M)	J-Mar-Frac	2415	58
20-Dec-10	9589	98601	JOS	KMI	Skovran #32H-24316 (M)	J-Mar-Frac	2415	58
20-Dec-10	9590	98602	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
20-Dec-10	9596	98608	JOS	WPK	Rau Unit #2H-25742 (M)	J-Mar-Brine	4166	99
20-Dec-10	9597	98609	JOS	BUR	Chubboy #5-20225	J-Brine	840	20
20-Dec-10	9597	98609	JOS	BUR	Chubboy #8-20228	J-Brine	1260	30
20-Dec-10	9597	98609	JOS	BUR	Chubboy #7-20227	J-Brine	2310	55
20-Dec-10	9600	98612	JOS	BUR	Painter #1-22656	J-Brine	1050	25
20-Dec-10	9600	98612	JOS	BUR	Skokut #9-22909	J-Brine	1470	35
20-Dec-10	9600	98612	JOS	BUR	Doney #8-22648	J-Brine	840	20
20-Dec-10	9600	98612	JOS	BUR	Doney #10-22650	J-Brine	1260	30
20-Dec-10	11602	98614	JOS	DII	National Mines #26H-25924 (M)	J-Mar-Brine	4200	100
20-Dec-10	11606	98618	JOS	BUR	Lynn #9-25758 (M)	J-Mar-Brine	4620	110
20-Dec-10	11607	98619	JOS	BUR	Serro #8-25304 (M)	J-Mar-Brine	4620	110
20-Dec-10	16017	155639	FKL	BUR	Hosler #7-24035 (M)	F-Mar-Brine	4200	100
20-Dec-10	16043	155667	FKL	BUR	Campbell #15-24302 (M)	F-Mar-Brine	4200	100
21-Dec-10	11616	98628	JOS	WPK	Rau Unit #2H-25742 (M)	J-Mar-Brine	4166	99
21-Dec-10	11618	98630	JOS	WSI	Yeagley #1-24507 (M)	J-Mar-Brine	4200	100
21-Dec-10	11619	98631	JOS	DII	Kovach #18-23200	J-Brine	2142	51
21-Dec-10	11619	98631	JOS	DII	Kovach #14-23197	J-Brine	1638	39
21-Dec-10	11627	98639	JOS	DEV	Honsaker #15-24492 (M)	J-Mar-Brine	3570	85
21-Dec-10	11628	98640	JOS	DEV	Wolfe #27-24410 (M)	J-Mar-Brine	4200	100
21-Dec-10	11636	98662	JOS	DII	Boord #4-21912	J-Brine	2730	65
21-Dec-10	11636	98662	JOS	DII	Polander #1-22237	J-Brine	1470	35
21-Dec-10	11647	98650	JOS	WSI	Clarke #14-22831 (M)	J-Mar-Brine	4200	100
21-Dec-10	11651	98654	JOS	BUR	Angelcyk #6-23649 (M)	J-Mar-Brine	4620	110
21-Dec-10	11654	98657	JOS	DII	Marolt/Kasievich #2-21769	J-Brine	3780	90
22-Dec-10	11640	98666	JOS	DII	Fay-Penn #44-24267 (M)C (M)	J-Mar-Brine	4200	100
22-Dec-10	11657	98669	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
22-Dec-10	11662	98674	JOS	DII	Irvine #2-21123	J-Brine	2058	49
22-Dec-10	11662	98674	JOS	DII	Genovese #3-16740	J-Brine	1512	36
22-Dec-10	11673	98685	JOS	DII	Green #3-20783	J-Brine	1890	45
22-Dec-10	11673	98685	JOS	DII	Keslar #9-23925 (M)	J-Mar-Brine	2268	54
22-Dec-10	11673	98685	JOS	DII	Masney #1-20586	J-Brine	42	1
22-Dec-10	11674	98686	JOS	BUR	Matty/Momyer #1-25650 (M)	J-Mar-Brine	4620	110
22-Dec-10	16170	155814	FKL	BUR	Phillips #21-24175 (M)	F-Mar-Brine	4200	100
22-Dec-10	16171	155815	FKL	BUR	Hosler #8-24695 (M)	F-Mar-Brine	4200	100
23-Dec-10	11699	98707	JOS	DII	Irvine #4-21918	J-Brine	1890	45
23-Dec-10	11699	98707	JOS	DII	Irvine #3-21314	J-Brine	1890	45
23-Dec-10	11704	98712	JOS	DII	Yeagley #1-24507 (M)	J-Mar-Brine	4200	100
23-Dec-10	11710	98718	JOS	WPK	McGrath Unit #1-30425 (M)	J-Mar-Brine	4166	99
23-Dec-10	11715	98723	JOS	DEV	Kovalic #13-24937 (M)	J-Mar-Brine	4200	100
23-Dec-10	11716	98724	JOS	DEV	Kovalic #13-24937 (M)	J-Mar-Brine	3570	85

23-Dec-10	11720	98729	JOS	WPK	Rau Unit #2H-25742 (M)	J-Mar-Brine	4166	99
23-Dec-10	11740	98742	JOS	WPK	Huczko #2-30418 (M)	J-Mar-Brine	4166	99
23-Dec-10	11741	98743	JOS	DII	J & J Realty #2-21004	J-Brine	2184	52
23-Dec-10	11741	98743	JOS	DII	J & J Realty #3-21005	J-Brine	1596	38
23-Dec-10	11742	98744	JOS	DII	Croftcheck #15-21302	J-Brine	2100	50
23-Dec-10	11742	98744	JOS	DII	J & J Realty #4-21006	J-Brine	2100	50
27-Dec-10	11757	98763	JOS	DII	Gaydos #7-21799	J-Brine	1890	45
27-Dec-10	11757	98763	JOS	DII	Jarek #4-22478	J-Brine	1890	45
27-Dec-10	11759	98765	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
27-Dec-10	11767	98773	JOS	WPK	Rau Unit #2H-25742 (M)	J-Mar-Brine	4166	99
27-Dec-10	11771	98778	JOS	WPK	McGrath Unit #1-30425 (M)	J-Mar-Brine	4166	99
27-Dec-10	11772	98779	JOS	KMI	Balazick #8H-25901 (M)	J-Mar-Frac	4620	110
27-Dec-10	11775	98782	JOS	DII	Headlee #8-25060 (M)	J-Mar-Brine	2100	50
27-Dec-10	11775	98782	JOS	DII	Headlee #9-25061 (M)	J-Mar-Brine	2100	50
27-Dec-10	11778	98785	JOS	WSI	Yeagley #1-24507 (M)	J-Mar-Brine	4200	100
27-Dec-10	11780	98789	JOS	KMI	Balazick #8H-25901 (M)	J-Mar-Frac	4620	110
27-Dec-10	11781	98788	JOS	KMI	Balazick #8H-25901 (M)	J-Mar-Frac	5460	130
27-Dec-10	11782	98790	JOS	KMI	Balazick #8H-25901 (M)	J-Mar-Frac	5460	130
27-Dec-10	11783	98791	JOS	KMI	Balazick #8H-25901 (M)	J-Mar-Frac	5460	130
28-Dec-10	10804	155987	FKL	BUR	Serro #8-25304 (M)	F-Mar-Brine	4200	100
28-Dec-10	10846	156029	FKL	BUR	Shoaf #8-23700 (M)	F-Mar-Brine	4200	100
28-Dec-10	11786	98794	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
28-Dec-10	11789	98797	JOS	WSI	Yeagley #1-24507 (M)	J-Mar-Brine	4200	100
28-Dec-10	11791	98799	JOS	WPK	Rau Unit #2H-25742 (M)	J-Mar-Brine	4166	99
28-Dec-10	11802	98811	JOS	KMI	Balazick #9H-25958 (M)	J-Mar-Frac	5040	120
28-Dec-10	11803	98812	JOS	KMI	Balazick #9H-25958 (M)	J-Mar-Frac	4830	115
28-Dec-10	11804	98813	JOS	KMI	Skovran #26H (M)	J-Mar-Frac	4200	100
28-Dec-10	11805	98814	JOS	KMI	Balazick #9H-25958 (M)	J-Mar-Frac	4830	115
28-Dec-10	11806	98815	JOS	KMI	Skovran #26H (M)	J-Mar-Pit	5040	120
29-Dec-10	10901	156103	FKL	BUR	Labuda #4-22211	F-Brine	1386	33
29-Dec-10	10901	156103	FKL	BUR	Myers #4-22333	F-Brine	714	17
29-Dec-10	10901	156103	FKL	BUR	Serro #2-23487	F-Brine	2142	51
29-Dec-10	11817	98826	JOS	WSI	Clarke #14-22831 (M)	J-Mar-Brine	4200	100
29-Dec-10	11818	98827	JOS	DII	Vidovich #2-21999	J-Brine	2058	49
29-Dec-10	11818	98827	JOS	DII	Vidovich #1-21998	J-Brine	1764	42
29-Dec-10	11825	98835	JOS	WSI	Kepple #4-25106 (M)	J-Mar-Brine	4200	100
29-Dec-10	11837	98847	JOS	KMI	Balazick #9H-25958 (M)	J-Mar-Frac	4830	115
30-Dec-10	11838	98848	JOS	DII	Martin #31-23729	J-Brine	2268	54
30-Dec-10	11838	98848	JOS	DII	Pontorero #2-20091	J-Brine	1554	37
30-Dec-10	11845	98854	JOS	WPK	McGrath Unit #1-30425 (M)	J-Mar-Brine	4166	99
30-Dec-10	11851	98860	JOS	WSI	Yeagley #1-24507 (M)	J-Mar-Brine	4200	100
30-Dec-10	11852	98861	JOS	WPK	Rau Unit #1-30424 (M)	J-Mar-Brine	4166	99
							1,339,648	31,891

PENNSYLVANIA BRINE TREATMENT

BLX, INC.

233 North Park Drive, Kittanning, PA 16201

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
01-Dec-10	9123	98135	JOS	T&L	Reken, J. #3 (M)	J-Mar-Brine	4620	110
01-Dec-10	9136	98148	JOS	T&L	Reken, J. #3 (M)	J-Mar-Brine	4620	110
01-Dec-10	9150	98162	JOS	T&L	Reken, J. #3 (M)	J-Mar-Brine	4620	110
01-Dec-10	19512	154588	FKL	T&L	Sleppy, R. #1-86-6 (M)	F-Mar-Brine	4620	110
04-Dec-10	10336	154759	FKL	SCH	Cogley #1-1.378	F-Brine	1260	30
04-Dec-10	10336	154759	FKL	SCH	Dayton United Methodist Church #1	F-Brine	2940	70
08-Dec-10	9293	98305	JOS	K-C	Reken, J. #3 (M)	J-Mar-Brine	3360	80
08-Dec-10	9308	98320	JOS	K-C	Reken, J. #3 (M)	J-Mar-Brine	3360	80
08-Dec-10	9317	98329	JOS	K-C	Reken, J. #3 (M)	J-Mar-Brine	3360	80
08-Dec-10	9325	98337	JOS	K-C	Reken, J. #3 (M)	J-Mar-Brine	3360	80
10-Dec-10	9399	98411	JOS	K-C	Reken, J. #3 (M)	J-Mar-Brine	3360	80
14-Dec-10	9435	98447	JOS	T&L	Reken, J. #3 (M)	J-Mar-Brine	4620	110
14-Dec-10	9444	98456	JOS	T&L	Reken, J. #3 (M)	J-Mar-Brine	4620	110
14-Dec-10	9453	98465	JOS	T&L	Reken, J. #3 (M)	J-Mar-Brine	4620	110
14-Dec-10	9459	98471	JOS	T&L	Sleppy, R. #1-86-6 (M)	J-Mar-Brine	4620	110
14-Dec-10	9462	98474	JOS	T&L	Sleppy, R. #1-86-6 (M)	J-Mar-Brine	4620	110
21-Dec-10	11610	98622	JOS	T&L	Sleppy, R. #1-86-6 (M)	J-Mar-Brine	4620	110
23-Dec-10	11700	98708	JOS	T&L	Sleppy, R. #1-86-6 (M)	J-Mar-Brine	4620	110
31-Dec-10	10979	156192	FKL	COU	Lendrum Farm	F-Brine	3486	83
							75,306	1,793

PENNSYLVANIA BRINE TREATMENT, INC.

CHIEF OIL & GAS LLC

5956 Sherry Lane, Ste. #1500, Dallas, TX 75225

Manifest Date	Manifest #	Sampe#	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
02-Dec-10	9186	98198	JOS	STU	Rice Unit #2H (M)	J-Mar-Brine	4668	111
06-Dec-10	9231	98243	JOS	STU	Rice Unit #2H (M)	J-Mar-Brine	5012	119
09-Dec-10	10632	155013	FKL	KMI	Lytle Unit #1H (M)	F-Mar-Frac	5040	120
10-Dec-10	10666	155052	FKL	KMI	Lytle Unit #1H (M)	F-Mar-Frac	5040	120
13-Dec-10	9404	98416	JOS	STU	Rice Unit #1H (M)	J-Mar-Brine	5012	119
16-Dec-10	19483	155397	FKL	KMI	Lytle Unit #1H (M)	F-Mar-Frac	5460	130
20-Dec-10	9567	98579	JOS	STU	Rice Unit #1H (M)	J-Mar-Brine	5012	119
20-Dec-10	11603	98615	JOS	STU	Rice Unit #2H (M)	J-Mar-Brine	4914	117
27-Dec-10	11755	98761	JOS	STU	Rice Unit #2H (M)	J-Mar-Brine	5012	119
							45,170	**1,074**

PENNSYLVANIA BRINE TREATMENT

CONSOL ENERGY, INC.

1000 Consol Energy Drive, Canonsburg, PA 15317

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
01-Dec-10	9133	98145	JOS	K.V	Musser, Forest #4-8458	J-Brine	3192	76
01-Dec-10	9133	98145	JOS	K.V	Musser Forest #5320	J-Brine	546	13
03-Dec-10	9196	98208	JOS	WHT	Lamer, S. #1-00085	J-Brine	420	10
03-Dec-10	9196	98208	JOS	WHT	Lamer, Scott #4-15689	J-Brine	3990	95
03-Dec-10	9206	98218	JOS	WHT	Spicher, A.C. #2-05394	J-Brine	2100	50
03-Dec-10	9206	98218	JOS	WHT	McCombie, E.J. #1-05396	J-Brine	2100	50
06-Dec-10	9240	98252	JOS	WHT	Ecelbarger, R. Wade #4-05540	J-Brine	3150	75
06-Dec-10	9240	98252	JOS	WHT	Lindsey Coal Minning #6-14365	J-Brine	1050	25
07-Dec-10	9270	98282	JOS	WHT	Savings & Trust #2-15568	J-Brine	3150	75
07-Dec-10	9270	98282	JOS	WHT	Savings & Trust #3-15569	J-Brine	1050	25
08-Dec-10	9300	98312	JOS	WHT	Wissinger, J.B. #2-05458	J-Brine	2940	70
08-Dec-10	9300	98312	JOS	WHT	McCombie, E.J. #2-05454	J-Brine	1260	30
09-Dec-10	9337	98349	JOS	WHT	Wain-Grove Unit#3-14795	J-Brine	630	15
09-Dec-10	9337	98349	JOS	WHT	Ecelbarger, E. #4-6322	J-Brine	2520	60
09-Dec-10	9337	98349	JOS	WHT	Ecelbarger, E. #3-6292	J-Brine	1050	25
09-Dec-10	9350	98362	JOS	WHT	White, M.P. #4-15555	J-Brine	1050	25
09-Dec-10	9350	98362	JOS	WHT	White, Melvin #2-8013	J-Brine	3150	75
10-Dec-10	9370	98382	JOS	WHT	Stuby, James #6-5409	J-Brine	1050	25
10-Dec-10	9370	98382	JOS	WHT	Byers Heirs #6077	J-Brine	1470	35
10-Dec-10	9370	98382	JOS	WHT	Peffer, Howard M. #3-5444	J-Brine	1680	40
10-Dec-10	9373	98385	JOS	WHT	Risinger, M J. #5-15938 (M)	J-Mar-Brine	3990	95
10-Dec-10	9386	98398	JOS	WHT	Risinger, M J. #5-15938 (M)	J-Mar-Brine	2100	50
10-Dec-10	9386	98398	JOS	WHT	Edwards #5-15718 (M)	J-Mar-Brine	1890	45
14-Dec-10	9456	98468	JOS	WHT	Fiori, F.J. #1-08034	J-Brine	2940	70
14-Dec-10	9456	98468	JOS	WHT	Edwards #5-15718 (M)	J-Mar-Brine	1260	30
15-Dec-10	9508	98520	JOS	WHT	Nesbit, J.F. #10-14692	J-Brine	2940	70
15-Dec-10	9510	98522	JOS	WHT	Fitzgerald, W. #7-15870 (M)	J-Mar-Brine	1680	40
15-Dec-10	9510	98522	JOS	WHT	Greene #6-15031	J-Brine	2520	60
16-Dec-10	9518	98530	JOS	K.V	Kerotest Mfg. Co. #6-06041	J-Brine	756	18
16-Dec-10	9518	98530	JOS	K.V	Senchur Unit #5-15995	J-Brine	2982	71
20-Dec-10	9575	98587	JOS	WHT	Fitzgerald, W. #7-15870 (M)	J-Mar-Brine	3990	95
21-Dec-10	11611	98623	JOS	WHT	Elbell, E. #1139	J-Brine	1470	35
21-Dec-10	11611	98623	JOS	WHT	Dickey Lumber #2-1069	J-Brine	2730	65
21-Dec-10	11620	98632	JOS	WHT	Edwards #5-15718 (M)	J-Mar-Brine	630	15
21-Dec-10	11620	98632	JOS	WHT	Hovis, A.P. #5-15556	J-Brine	3570	85
21-Dec-10	11644	98647	JOS	WHT	Fiori, F.J. #1-08034	J-Brine	420	10
21-Dec-10	11644	98647	JOS	WHT	Fox, Walter #1-7998	J-Brine	3780	90
23-Dec-10	11714	98722	JOS	WHT	Peffer, Howard M. #5-5410	J-Brine	3150	75
29-Dec-10	11813	98822	JOS	WHT	Travis, J. #WEPA1042	J-Brine	2940	70
30-Dec-10	11840	98849	JOS	WHT	Mabon Lindsay Coal #6279	J-Brine	630	15
30-Dec-10	11840	98849	JOS	WHT	Rishel, M. #2-1142	J-Brine	2730	65
30-Dec-10	11853	98862	JOS	WHT	Fitzgerald, W. #7-15870 (M)	J-Mar-Brine	2940	70
							89,586	2,133

PENNSYLVANIA BRINE TREATMENT, INC.

EOG RESOURCES

2039 South 6th Street, Indiana, PA 15701

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
01-Dec-10	9116	98128	JOS	BUR	Seimen #1H (M)	J-Mar-Pit	4620	110
01-Dec-10	9117	98129	JOS	BUR	Seimen #1H (M)	J-Mar-Pit	4620	110
01-Dec-10	9118	98130	JOS	BUR	Seimen #1H (M)	J-Mar-Pit	4620	110
01-Dec-10	10022	154523	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
01-Dec-10	10023	154551	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
01-Dec-10	10024	154582	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
01-Dec-10	10057	154564	FKL	SWS	Punxsy Hunting Club K Pad (M)	F-Mar-Pit	4410	105
01-Dec-10	10058	154530	FKL	SWS	Punxsy Hunting Club #23H (M)	F-Mar-Brine	2268	54
01-Dec-10	10058	154530	FKL	SWS	Punxsy Hunting Club #24H (M)	F-Mar-Brine	1732	41
01-Dec-10	10247	154516	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
01-Dec-10	10248	154517	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
01-Dec-10	10250	154520	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
01-Dec-10	10252	154522	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
01-Dec-10	10267	154539	FKL	BUR	Lee #1H (M)	F-Mar-Pit	5040	120
01-Dec-10	10269	154542	FKL	BUR	Lee #1H (M)	F-Mar-Pit	5460	130
01-Dec-10	10270	154544	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
01-Dec-10	10279	154557	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
01-Dec-10	18867	154572	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
01-Dec-10	18868	154519	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
01-Dec-10	18978	154540	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
01-Dec-10	19110	154529	FKL	SWS	Punxsy Hunting Club #9H (M)	F-Mar-Frac	4000	95
01-Dec-10	19111	154561	FKL	SWS	Punxsy Hunting Club #9H (M)	F-Mar-Pit	4200	100
01-Dec-10	19268	154536	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
01-Dec-10	19269	154566	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
01-Dec-10	19354	154526	FKL	SWS	Punxsy Hunting Club #3H (M)	F-Mar-Brine	4000	95
01-Dec-10	19355	154571	FKL	SWS	C.O.P. #5H-2316 (M)	F-Mar-Brine	4000	95
02-Dec-10	10025	154598	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
02-Dec-10	10026	154632	FKL	SWS	Punxsy Hunting Club #3H (M)	F-Mar-Brine	4000	95
02-Dec-10	10055	154631	FKL	SWS	Punxsy Hunting Club #7H (M)	F-Mar-Brine	4000	95
02-Dec-10	10056	154597	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
02-Dec-10	18866	154622	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
02-Dec-10	18979	154593	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
02-Dec-10	19112	154599	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4200	100
02-Dec-10	19113	154642	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
02-Dec-10	19356	154592	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
02-Dec-10	19357	154615	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
02-Dec-10	19358	154647	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
02-Dec-10	19514	154590	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
02-Dec-10	19515	154591	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
02-Dec-10	19522	154606	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
02-Dec-10	19523	154607	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119

02-Dec-10	19536	154613	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
02-Dec-10	19545	154627	FKL	BUR	Seimen #1H (M)	F-Mar-Pit	5460	130
02-Dec-10	19546	154628	FKL	BUR	Seimen #1H (M)	F-Mar-Pit	5040	120
02-Dec-10	19567	154646	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
02-Dec-10	19585	154664	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
03-Dec-10	10027	154677	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
03-Dec-10	10028	154714	FKL	SWS	Punxsy Hunting Club #7H (M)	F-Mar-Brine	4000	95
03-Dec-10	10053	154715	FKL	SWS	Punxsy Hunting Club #3H (M)	F-Mar-Brine	4000	95
03-Dec-10	10054	154675	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
03-Dec-10	10310	154718	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
03-Dec-10	10329	154690	FKL	SWS	Ward #1H (M)	F-Mar-Brine	4400	105
03-Dec-10	10330	154692	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
03-Dec-10	10402	154701	FKL	SWS	C.O.P. #6H-2316 (M)	F-Mar-Brine	4000	95
03-Dec-10	10405	154706	FKL	BUR	Seimen #1H (M)	F-Mar-Pit	5460	130
03-Dec-10	10406	154707	FKL	BUR	Seimen #1H (M)	F-Mar-Pit	5040	120
03-Dec-10	10408	154708	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4200	100
03-Dec-10	10437	154728	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
03-Dec-10	10440	154732	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
03-Dec-10	10442	154734	FKL	BEI	S.R.C. #6H (M)	F-Mar-Frac	4200	100
03-Dec-10	10443	154735	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
03-Dec-10	10444	154736	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
03-Dec-10	18865	154667	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
03-Dec-10	19114	154673	FKL	SWS	C.O.P. #8H-4093 (M)	F-Mar-Brine	4000	95
03-Dec-10	19115	154730	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
03-Dec-10	19205	154666	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	5040	120
03-Dec-10	19267	154682	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
03-Dec-10	19270	154711	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
03-Dec-10	19586	154670	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
03-Dec-10	19588	154684	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
03-Dec-10	19599	154669	FKL	SWS	C.O.P. #3H-4093 (M)	F-Mar-Brine	4000	95
04-Dec-10	10311	154755	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4149	99
04-Dec-10	10312	154765	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4108	98
04-Dec-10	10321	154743	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4093	97
04-Dec-10	10445	154737	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
04-Dec-10	10452	154740	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
04-Dec-10	10453	154753	FKL	BEI	S.R.C. #6H (M)	F-Mar-Frac	3780	90
04-Dec-10	10455	154742	FKL	BEI	Punxsy Hunting Club #36H (M)	F-Mar-Frac	4620	110
04-Dec-10	10487	154745	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4400	105
04-Dec-10	10488	154747	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
04-Dec-10	10500	154758	FKL	SWS	Punxsy Hunting Club #3H (M)	F-Mar-Brine	1680	40
04-Dec-10	10500	154758	FKL	SWS	Punxsy Hunting Club #7H (M)	F-Mar-Brine	2720	65
04-Dec-10	19037	154739	FKL	SWS	Punxsy Hunting Club #24H (M)	F-Mar-Brine	4000	95
04-Dec-10	19038	154750	FKL	SWS	Punxsy Hunting Club #35H (M)	F-Mar-Brine	4000	95
04-Dec-10	19109	154751	FKL	SWS	Punxsy Hunting Club #3H (M)	F-Mar-Brine	850	20
04-Dec-10	19109	154751	FKL	SWS	Punxsy Hunting Club #8H (M)	F-Mar-Brine	3150	75
04-Dec-10	19116	154763	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
04-Dec-10	19359	154744	FKL	SWS	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4000	95
04-Dec-10	19360	154756	FKL	SWS	Punxsy Hunting Club #2H (M)	F-Mar-Brine	4000	95
04-Dec-10	19587	154741	FKL	BEI	S.R.C. #6H (M)	F-Mar-Frac	5040	120

06-Dec-10	10029	154776	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
06-Dec-10	10030	154806	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
06-Dec-10	10051	154805	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
06-Dec-10	10052	154769	FKL	SWS	Punxsy Hunting Club #3H (M)	F-Mar-Brine	4000	95
06-Dec-10	10282	154771	FKL	SWS	Punxsy Hunting Club #9H (M)	F-Mar-Brine	4000	95
06-Dec-10	10283	154811	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
06-Dec-10	10313	154767	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
06-Dec-10	10338	154773	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4200	100
06-Dec-10	10340	154775	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
06-Dec-10	10342	154778	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
06-Dec-10	10350	154794	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4200	100
06-Dec-10	10356	154799	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4200	100
06-Dec-10	10361	154804	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
06-Dec-10	19271	154807	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
06-Dec-10	19272	154782	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
06-Dec-10	19361	154770	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
06-Dec-10	19362	154786	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
06-Dec-10	19363	154814	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
06-Dec-10	19598	154785	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
07-Dec-10	10031	154831	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
07-Dec-10	10032	154874	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
07-Dec-10	10049	154875	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
07-Dec-10	10050	154844	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
07-Dec-10	10284	154832	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
07-Dec-10	10285	154885	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
07-Dec-10	10320	154856	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
07-Dec-10	10454	154841	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
07-Dec-10	10501	154883	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
07-Dec-10	10502	154843	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
07-Dec-10	10503	154845	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
07-Dec-10	10512	154855	FKL	SWS	Houseknecht #3H (M)	F-Mar-Brine	4400	105
07-Dec-10	10521	154879	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
07-Dec-10	10523	154882	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
07-Dec-10	19273	154842	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
07-Dec-10	19274	154872	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
07-Dec-10	19364	154833	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
07-Dec-10	19365	154881	FKL	SWS	C.O.P. #3H-4093 (M)	F-Mar-Brine	4000	95
07-Dec-10	19591	154830	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
08-Dec-10	10033	154900	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
08-Dec-10	10034	154940	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
08-Dec-10	10047	154939	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
08-Dec-10	10048	154901	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
08-Dec-10	10286	154898	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
08-Dec-10	10287	154950	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
08-Dec-10	10456	154905	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
08-Dec-10	10457	154951	FKL	SWS	C.O.P. #8H-4093 (M)	F-Mar-Brine	4000	95
08-Dec-10	10549	154893	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
08-Dec-10	10553	154904	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
08-Dec-10	10555	154908	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4200	100

08-Dec-10	10559	154912	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
08-Dec-10	10565	154921	FKL	SWS	Houseknecht #2H (M)	F-Mar-Brine	4400	105
08-Dec-10	10571	154931	FKL	BEI	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4620	110
08-Dec-10	10576	154941	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4200	100
08-Dec-10	19275	154915	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	5000	119
08-Dec-10	19276	154943	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	5000	119
08-Dec-10	19592	154895	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
08-Dec-10	19593	154919	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
09-Dec-10	10035	154967	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
09-Dec-10	10036	155008	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
09-Dec-10	10061	155009	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
09-Dec-10	10062	154966	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
09-Dec-10	10288	154968	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
09-Dec-10	10289	155010	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
09-Dec-10	10318	154963	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
09-Dec-10	10458	154964	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
09-Dec-10	10460	154991	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
09-Dec-10	10594	154973	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
09-Dec-10	10595	154975	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
09-Dec-10	10597	155004	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
09-Dec-10	10626	154998	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	5460	130
09-Dec-10	10627	155000	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
09-Dec-10	10631	155017	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
09-Dec-10	10635	155014	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
09-Dec-10	10636	155015	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
09-Dec-10	19277	154978	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	5000	119
09-Dec-10	19278	154999	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	5000	119
09-Dec-10	19594	154986	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
10-Dec-10	10037	155034	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
10-Dec-10	10038	155065	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
10-Dec-10	10060	155036	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
10-Dec-10	10290	155037	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
10-Dec-10	10316	155062	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
10-Dec-10	10317	155027	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
10-Dec-10	10461	155039	FKL	SWS	C.O.P. #3H-4093 (M)	F-Mar-Brine	4000	95
10-Dec-10	10639	155023	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
10-Dec-10	10640	155024	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
10-Dec-10	10641	155025	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4200	100
10-Dec-10	10642	155026	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
10-Dec-10	10643	155028	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
10-Dec-10	10644	155029	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4200	100
10-Dec-10	10648	155033	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	3990	95
10-Dec-10	10651	155041	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
10-Dec-10	10667	155053	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	3990	95
10-Dec-10	10668	155054	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-10%-Frac	4620	110
10-Dec-10	10672	155064	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-10%-Frac	4620	110
10-Dec-10	10675	155071	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	3990	95
10-Dec-10	10676	155072	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-10%-Frac	4620	110
10-Dec-10	10677	155073	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110

10-Dec-10	10678	155078	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
10-Dec-10	10701	155079	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-10%-Frac	4620	110
10-Dec-10	19178	155066	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
10-Dec-10	19279	155063	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
10-Dec-10	19280	155043	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
10-Dec-10	19595	155042	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
11-Dec-10	10039	155086	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
11-Dec-10	10040	155097	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
11-Dec-10	10315	155095	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
11-Dec-10	10459	155105	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	100
11-Dec-10	10466	155111	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
11-Dec-10	10491	155106	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
11-Dec-10	10492	155085	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
11-Dec-10	10702	155082	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
11-Dec-10	10703	155081	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
11-Dec-10	10704	155083	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
11-Dec-10	10705	155092	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
11-Dec-10	10706	155087	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
11-Dec-10	10707	155088	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
11-Dec-10	10708	155090	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	3990	95
11-Dec-10	10709	155108	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	3990	95
11-Dec-10	10715	155098	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
11-Dec-10	19177	155091	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
11-Dec-10	19596	155084	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
11-Dec-10	19597	155107	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
12-Dec-10	10743	155116	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
12-Dec-10	10744	155119	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
12-Dec-10	10745	155117	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
12-Dec-10	10746	155118	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4200	100
12-Dec-10	10752	155120	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4200	100
12-Dec-10	10753	155121	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
13-Dec-10	10041	155124	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
13-Dec-10	10042	155162	FKL	SWS	Punxsy Hunting Club #3H (M)	F-Mar-Brine	4000	95
13-Dec-10	10314	155123	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
13-Dec-10	10465	155122	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
13-Dec-10	10493	155141	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
13-Dec-10	10494	155172	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
13-Dec-10	10684	155173	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4200	100
13-Dec-10	10685	155174	FKL	SWS	Punxsy Hunting Club B Pad (M)	F-Mar-Brine	4200	100
13-Dec-10	10687	155178	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
13-Dec-10	10710	155129	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	3990	95
13-Dec-10	10711	155157	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	3990	95
13-Dec-10	10754	155128	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
13-Dec-10	10760	155137	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4200	100
13-Dec-10	10761	155138	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
13-Dec-10	10790	155183	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
13-Dec-10	1772	155158	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
13-Dec-10	19175	155161	FKL	SWS	Punxsy Hunting Club #7H (M)	F-Mar-Brine	4000	95
13-Dec-10	19176	155125	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95

13-Dec-10	19402	155184	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
13-Dec-10	19405	155192	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
13-Dec-10	19590	155151	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
14-Dec-10	10043	155204	FKL	SWS	Punxsy Hunting Club #23H (M)	F-Mar-Brine	4000	95
14-Dec-10	10447	155203	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
14-Dec-10	10448	155231	FKL	SWS	C.O.P. #3H-4093 (M)	F-Mar-Brine	4000	95
14-Dec-10	10462	155219	FKL	SWS	Punxsy Hunting Club #24H (M)	F-Mar-Brine	4000	95
14-Dec-10	10467	155195	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
14-Dec-10	10495	155232	FKL	SWS	C.O.P. #8H-4093 (M)	F-Mar-Brine	4000	95
14-Dec-10	10496	155202	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
14-Dec-10	10712	155223	FKL	SWS	Punxsy Hunting Club #3H (M)	F-Mar-Brine	3990	95
14-Dec-10	10725	155222	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
14-Dec-10	10748	155243	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
14-Dec-10	10749	155198	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
14-Dec-10	10791	155194	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
14-Dec-10	14968	155224	FKL	SWS	Punxsy Hunting Club B Pad (M)	F-Mar-Frac	4800	114
14-Dec-10	15608	155256	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4200	100
14-Dec-10	15610	155261	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	5040	120
14-Dec-10	19408	155196	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	3990	95
14-Dec-10	19423	155209	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
14-Dec-10	19424	155242	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
14-Dec-10	19429	155211	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
14-Dec-10	19465	155262	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
15-Dec-10	10044	155300	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
15-Dec-10	10449	155269	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
15-Dec-10	10450	155319	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
15-Dec-10	10463	155267	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
15-Dec-10	10464	155314	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
15-Dec-10	10497	155270	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
15-Dec-10	10498	155318	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
15-Dec-10	10713	155271	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	3990	95
15-Dec-10	10750	155265	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
15-Dec-10	10751	155285	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
15-Dec-10	10792	155266	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
15-Dec-10	10793	155297	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
15-Dec-10	15611	155340	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
15-Dec-10	15613	155264	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
15-Dec-10	15614	155273	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
15-Dec-10	15633	155302	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	3990	95
15-Dec-10	15634	155306	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
15-Dec-10	15639	155317	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
15-Dec-10	1.564E+09	155321	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4200	100
15-Dec-10	19281	155277	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
15-Dec-10	19282	155305	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
16-Dec-10	10045	155348	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
16-Dec-10	10046	155382	FKL	SWS	Punxsy Hunting Club #9H (M)	F-Mar-Brine	4000	95
16-Dec-10	10451	155351	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
16-Dec-10	10779	155352	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
16-Dec-10	10794	155344	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95

16-Dec-10	10795	155370	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
16-Dec-10	10798	155411	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
16-Dec-10	15663	155345	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
16-Dec-10	15664	155346	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	3990	95
16-Dec-10	15666	155378	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	3990	95
16-Dec-10	15687	155379	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
16-Dec-10	15688	155380	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
16-Dec-10	15703	155424	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
16-Dec-10	19174	155349	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
16-Dec-10	19283	155358	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
16-Dec-10	19284	155398	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
16-Dec-10	19425	155343	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
16-Dec-10	19475	155387	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4200	100
16-Dec-10	19484	155401	FKL	SWS	Punxsy Hunting Club #7H (M)	F-Mar-Brine	4000	95
16-Dec-10	19497	155419	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
17-Dec-10	10468	155448	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
17-Dec-10	10469	155492	FKL	SWS	C.O.P. #8H-4093 (M)	F-Mar-Brine	4000	95
17-Dec-10	10680	155464	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
17-Dec-10	10780	155450	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
17-Dec-10	10781	155494	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
17-Dec-10	10796	155444	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
17-Dec-10	10797	155496	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
17-Dec-10	15256	155452	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
17-Dec-10	15257	155493	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
17-Dec-10	15692	155453	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
17-Dec-10	15715	155439	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
17-Dec-10	15716	155440	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
17-Dec-10	15717	155441	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
17-Dec-10	15735	155449	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4200	100
17-Dec-10	15759	155497	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
17-Dec-10	15788	155465	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
17-Dec-10	15793	155477	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4200	100
17-Dec-10	15804	155486	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
17-Dec-10	15805	155512	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
17-Dec-10	15838	155503	FKL	BEI	Punxsy Hunting Club #37H (M)	F-Mar-Frac	4620	110
17-Dec-10	19285	155456	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
18-Dec-10	10470	155531	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
18-Dec-10	10471	155549	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
18-Dec-10	10782	155529	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
18-Dec-10	10783	155548	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
18-Dec-10	15258	155530	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
18-Dec-10	15259	155547	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
18-Dec-10	15693	155542	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
18-Dec-10	15760	155536	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4100	98
18-Dec-10	15761	155558	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4100	98
18-Dec-10	15766	155550	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4100	98
18-Dec-10	15803	155518	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
18-Dec-10	15850	155520	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
18-Dec-10	15875	155539	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110

21-Dec-10	16049	155673	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
21-Dec-10	16052	155677	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
21-Dec-10	16053	155678	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4400	105
21-Dec-10	16054	155682	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
21-Dec-10	16055	155683	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4830	115
21-Dec-10	16056	155684	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
21-Dec-10	16057	155712	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4830	115
21-Dec-10	16061	155685	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4200	100
21-Dec-10	16065	155738	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
21-Dec-10	16080	155693	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4400	105
21-Dec-10	16115	155746	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
21-Dec-10	16117	155748	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
21-Dec-10	16118	155749	FKL	GFS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
21-Dec-10	16120	155751	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
22-Dec-10	4436	155768	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4200	100
22-Dec-10	4437	155800	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4400	105
22-Dec-10	10128	155793	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
22-Dec-10	10129	155763	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
22-Dec-10	10717	155827	FKL	DEN	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
22-Dec-10	10719	155761	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
22-Dec-10	10723	155785	FKL	DEN	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
22-Dec-10	10788	155824	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
22-Dec-10	10789	155777	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
22-Dec-10	15264	155776	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
22-Dec-10	15265	155823	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
22-Dec-10	15763	155829	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
22-Dec-10	15764	155790	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
22-Dec-10	16066	155792	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
22-Dec-10	16067	155830	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
22-Dec-10	16119	155756	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
22-Dec-10	16123	155754	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
22-Dec-10	16124	155755	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
22-Dec-10	16125	155770	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
22-Dec-10	16126	155757	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
22-Dec-10	16127	155760	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4200	100
22-Dec-10	16128	155762	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4400	105
22-Dec-10	16130	155766	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
22-Dec-10	16131	155767	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
22-Dec-10	16133	155772	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
22-Dec-10	16137	155780	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4200	100
22-Dec-10	16141	155786	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4400	105
22-Dec-10	16146	155795	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
22-Dec-10	16169	155812	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
22-Dec-10	16174	155818	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
22-Dec-10	16176	155820	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
23-Dec-10	10130	155842	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
23-Dec-10	10131	155858	FKL	SWS	Punxsy Hunting Club G Pad (M)	F-Mar-Frac	4000	95
23-Dec-10	10727	98749	JOS	DEN	Punxsy Hunting Club H Pad (M)	J-Mar-Frac	5000	119
23-Dec-10	10728	98748	JOS	DEN	Punxsy Hunting Club G Pad (M)	J-Mar-Frac	4000	95

23-Dec-10	11693	98700	JOS	SWS	Punxsy Hunting Club G Pad (M)	J-Mar-Frac	4000	95
23-Dec-10	11695	98704	JOS	SWS	Punxsy Hunting Club G Pad (M)	J-Mar-Frac	4200	100
23-Dec-10	11696	98703	JOS	SWS	Punxsy Hunting Club G Pad (M)	J-Mar-Frac	4400	105
23-Dec-10	11697	98705	JOS	SWS	Punxsy Hunting Club H Pad (M)	J-Mar-Frac	4200	100
23-Dec-10	11709	98717	JOS	SWS	Punxsy Hunting Club G Pad (M)	J-Mar-Frac	4100	98
23-Dec-10	11717	98725	JOS	SWS	Punxsy Hunting Club H Pad (M)	J-Mar-Frac	4200	100
23-Dec-10	11736	98738	JOS	SWS	Punxsy Hunting Club G Pad (M)	J-Mar-Frac	4200	100
23-Dec-10	11739	98741	JOS	SWS	Punxsy Hunting Club G Pad (M)	J-Mar-Frac	4400	105
23-Dec-10	15694	155853	FKL	SWS	Punxsy Hunting Club #24H (M)	F-Mar-Brine	4000	95
23-Dec-10	15695	98736	JOS	SWS	Punxsy Hunting Club G Pad (M)	J-Mar-Frac	4200	100
23-Dec-10	15765	98754	JOS	DEN	Punxsy Hunting Club H Pad (M)	J-Mar-Frac	4500	107
23-Dec-10	15767	155861	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4500	107
23-Dec-10	16068	155841	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
23-Dec-10	16191	155840	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
23-Dec-10	16192	155855	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
23-Dec-10	16193	155856	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
23-Dec-10	16194	155843	FKL	GFS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
23-Dec-10	16196	155844	FKL	GFS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
23-Dec-10	16198	155847	FKL	GFS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	3780	90
23-Dec-10	16237	155860	FKL	GFS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
23-Dec-10	16241	155868	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
23-Dec-10	16245	155872	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
23-Dec-10	16254	155882	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
23-Dec-10	19169	155854	FKL	SWS	Punxsy Hunting Club #23H (M)	F-Mar-Frac	4200	100
23-Dec-10	19170	98737	JOS	SWS	Punxsy Hunting Club G Pad (M)	J-Mar-Frac	4200	100
27-Dec-10	2607	155901	FKL	SWS	Punxsy Hunting Club #37H (M)	F-Mar-Brine	4000	95
27-Dec-10	10132	155890	FKL	SWS	Punxsy Hunting Club #3H (M)	F-Mar-Frac	4000	95
27-Dec-10	10133	155919	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
27-Dec-10	10683	155900	FKL	SWS	Punxsy Hunting Club #9H (M)	F-Mar-Brine	4000	95
27-Dec-10	10716	155888	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
27-Dec-10	10724	155921	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
27-Dec-10	15266	155899	FKL	SWS	Punxsy Hunting Club #36H (M)	F-Mar-Frac	4000	95
27-Dec-10	15696	155894	FKL	SWS	Punxsy Hunting Club #23H (M)	F-Mar-Brine	4000	95
27-Dec-10	15768	155935	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
27-Dec-10	15769	155908	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
27-Dec-10	15807	155927	FKL	SWS	Punxsy Hunting Club #8H (M)	F-Mar-Brine	4000	95
27-Dec-10	15958	155926	FKL	SWS	Punxsy Hunting Club #7H (M)	F-Mar-Brine	4000	95
27-Dec-10	16058	155893	FKL	SWS	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4830	115
27-Dec-10	16059	155922	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4830	115
27-Dec-10	16070	155907	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
27-Dec-10	16071	155931	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
27-Dec-10	16234	155895	FKL	SWS	Punxsy Hunting Club #25H (M)	F-Mar-Brine	4200	100
27-Dec-10	16256	155889	FKL	SWS	Punxsy Hunting Club #24H (M)	F-Mar-Brine	4160	99
27-Dec-10	16280	155898	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
27-Dec-10	16281	155902	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
27-Dec-10	16283	155904	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
27-Dec-10	16294	155920	FKL	SWS	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4120	98
27-Dec-10	16297	155928	FKL	BEI	Punxsy Hunting Club K Pad (M)	F-Mar-Frac	4620	110
27-Dec-10	16320	155934	FKL	BEI	Punxsy Hunting Club E Pad (M)	REJECTED	0	0

27-Dec-10	16321	155936	FKL	BEI	Punxsy Hunting Club E Pad (M)	REJECTED	0	0
27-Dec-10	16340	155945	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-10%-Frac	4620	110
27-Dec-10	16341	155947	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
27-Dec-10	16342	155948	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
27-Dec-10	19039	155924	FKL	SWS	Punxsy Hunting Club #24H (M)	F-Mar-Brine	4000	95
28-Dec-10	1776	155978	FKL	SWS	Punxsy Hunting Club #35H (M)	F-Mar-Frac	4000	95
28-Dec-10	10681	155992	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
28-Dec-10	10682	155965	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4000	95
28-Dec-10	10801	155981	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
28-Dec-10	10839	156001	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
28-Dec-10	10840	156005	FKL	SWS	Punxsy Hunting Club #36H (M)	F-Mar-Brine	4025	96
28-Dec-10	10842	156012	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
28-Dec-10	10843	156027	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
28-Dec-10	10844	156041	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
28-Dec-10	15697	155976	FKL	SWS	Punxsy Hunting Club #23H (M)	F-Mar-Frac	4000	95
28-Dec-10	15770	156016	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
28-Dec-10	15771	155982	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
28-Dec-10	15959	155980	FKL	SWS	Punxsy Hunting Club #9H (M)	F-Mar-Brine	4000	95
28-Dec-10	15960	156015	FKL	SWS	Punxsy Hunting Club #7H (M)	F-Mar-Brine	4000	95
28-Dec-10	16353	155954	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
28-Dec-10	16368	155958	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
28-Dec-10	16369	155959	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
28-Dec-10	16378	155963	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
28-Dec-10	16380	155966	FKL	SWS	Punxsy Hunting Club #36H (M)	F-Mar-Frac	4100	98
28-Dec-10	16381	155969	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
28-Dec-10	19040	155977	FKL	SWS	Punxsy Hunting Club #24H (M)	F-Mar-Brine	4000	95
28-Dec-10	19041	156014	FKL	SWS	Punxsy Hunting Club #23H (M)	F-Mar-Brine	4000	95
28-Dec-10	19171	155983	FKL	SWS	Punxsy Hunting Club #25H (M)	F-Mar-Brine	3444	82
28-Dec-10	19171	155983	FKL	SWS	Punxsy Hunting Club #35H (M)	F-Mar-Brine	756	18
29-Dec-10	10720	156058	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
29-Dec-10	10721	156070	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
29-Dec-10	10851	156048	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
29-Dec-10	10857	156054	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
29-Dec-10	10859	156057	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
29-Dec-10	10860	156059	FKL	BEI	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4620	110
29-Dec-10	10861	156060	FKL	SWS	Punxsy Hunting Club #36H (M)	F-Mar-Brine	4030	96
29-Dec-10	10868	156066	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	4620	110
29-Dec-10	10869	156068	FKL	BEI	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	4620	110
29-Dec-10	10885	156082	FKL	SWS	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4310	103
29-Dec-10	10906	156119	FKL	BEI	Punxsy Hunting Club #38H (M)	F-Mar-Frac	5040	120
29-Dec-10	15698	156064	FKL	SWS	Punxsy Hunting Club #23H (M)	F-Mar-Brine	4000	95
29-Dec-10	15772	156098	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	5000	119
29-Dec-10	15773	156069	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
29-Dec-10	15808	156065	FKL	SWS	Punxsy Hunting Club #24H (M)	F-Mar-Frac	4000	95
29-Dec-10	15809	156093	FKL	SWS	Punxsy Hunting Club #38H (M)	F-Mar-Brine	4059	97
29-Dec-10	15810	156110	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
29-Dec-10	15961	156113	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
29-Dec-10	16069	156071	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119
29-Dec-10	16074	156099	FKL	DEN	Punxsy Hunting Club E Pad (M)	F-Mar-Frac	5000	119

29-Dec-10	19042	156112	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
30-Dec-10	10729	156130	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
30-Dec-10	10730	156144	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	4000	95
30-Dec-10	10845	156128	FKL	BEI	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4620	110
30-Dec-10	10908	156127	FKL	BEI	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4620	110
30-Dec-10	10927	156143	FKL	BEI	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4620	110
30-Dec-10	10928	156175	FKL	BEI	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4620	110
30-Dec-10	10929	156160	FKL	BEI	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4620	110
30-Dec-10	10930	156142	FKL	BEI	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4620	110
30-Dec-10	10944	156133	FKL	SWS	Punxsy Hunting Club #23H (M)	F-Mar-Brine	4020	96
30-Dec-10	10945	156146	FKL	SWS	Punxsy Hunting Club #23H (M)	F-Mar-Brine	4030	96
30-Dec-10	15699	156136	FKL	SWS	Punxsy Hunting Club Drip Line	F-Mar-Brine	600	14
30-Dec-10	15699	156136	FKL	SWS	Punxsy Hunting Club #3H (M)	F-Mar-Brine	3400	81
30-Dec-10	15774	156140	FKL	DEN	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	5000	119
30-Dec-10	15775	156157	FKL	DEN	Punxsy Hunting Club H Pad (M)	F-Mar-Frac	5000	119
30-Dec-10	15811	156139	FKL	SWS	Punxsy Hunting Club #36H (M)	F-Mar-Brine	4000	95
30-Dec-10	15812	156155	FKL	SWS	Punxsy Hunting Club #36H (M)	F-Mar-Brine	4000	95
30-Dec-10	15813	156179	FKL	SWS	Punxsy Hunting Club D Pad (M)	F-Mar-Frac	4000	95
30-Dec-10	15962	156141	FKL	SWS	Punxsy Hunting Club #24H (M)	F-Mar-Brine	4000	95
30-Dec-10	16233	156137	FKL	SWS	Punxsy Hunting Club #38H (M)	F-Mar-Brine	4200	100
30-Dec-10	19337	156138	FKL	SWS	Punxsy Hunting Club #35H (M)	F-Mar-Brine	4000	95
							2360844	**56166**

PENNSYLVANIA BRINE TREATMENT, INC.

EQT PRODUCTION

P.O. Box 23425, Pittsburgh, PA 15222

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
16-Dec-10	15679	155363	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4620	110
16-Dec-10	15680	155364	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
16-Dec-10	15681	155365	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
16-Dec-10	15682	155366	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
16-Dec-10	15690	155384	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4620	110
16-Dec-10	15691	155478	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
16-Dec-10	19474	155386	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
16-Dec-10	19478	155390	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
16-Dec-10	19480	155394	FKL	P.M	Barrett #590370 (M)	F-Mar-Pit 10%	2940	70
16-Dec-10	19489	155404	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4620	110
16-Dec-10	19491	155408	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
16-Dec-10	19492	155409	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
16-Dec-10	19493	155410	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
17-Dec-10	15784	155458	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
17-Dec-10	15785	155459	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
17-Dec-10	15786	155462	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4620	110
17-Dec-10	15787	155463	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
17-Dec-10	15797	155479	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4620	110
17-Dec-10	15798	155480	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
17-Dec-10	15801	155484	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
17-Dec-10	15806	155487	FKL	WPE	Wedekind, F. #590389 (M)	F-Mar-Pit	4200	100
21-Dec-10	11625	98637	JOS	WPE	Royal #590259 (M)	J-Mar-Brine	4200	100
21-Dec-10	11646	98649	JOS	WPE	Royal #590259 (M)	J-Mar-Brine	4200	100
30-Dec-10	10951	156162	FKL	WPK	Barrett #590371 (M)	F-Mar-Frac	4200	100
30-Dec-10	10960	156165	FKL	WPK	Barrett #590371 (M)	F-Mar-Frac	3360	80
30-Dec-10	10961	156166	FKL	WPK	Barrett #590371 (M)	F-Mar-Frac	3360	80
30-Dec-10	10962	156167	FKL	WPK	Barrett #590371 (M)	F-Mar-Frac	4200	100
							112560	2680

PENNYSLVANIA BRINE TREATMENT, INC.

EXCO RESOURCES, INC.

3000 Ericsson Drive Ste. 200, Warrendale, PA 15086

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
01-Dec-10	9158	98170	JOS	WHT	Tomb, D. #2-150285	J-Brine	3360	80
02-Dec-10	9161	98174	JOS	WHT	Penns Manor #2-203065	J-Brine	1890	45
02-Dec-10	9161	98174	JOS	WHT	Cramer #3-203007	J-Brine	1890	45
02-Dec-10	9164	98176	JOS	WHT	Sickenberger #1-202508	J-Brine	1596	38
02-Dec-10	9164	98176	JOS	WHT	Heron #2-203024	J-Brine	1596	38
02-Dec-10	9182	98194	JOS	WHT	Shannon Land & Mining #4-203681	J-Brine	1680	40
02-Dec-10	9182	98194	JOS	WHT	McFadden #11-203701	J-Brine	1680	40
03-Dec-10	9200	98212	JOS	WHT	Yanity 002-203379	J-Brine	3780	90
03-Dec-10	9205	98217	JOS	WHT	Thornsberry #1-203375	J-Brine	3990	95
03-Dec-10	9215	98227	JOS	WHT	Ralston, J.S. #2-150289	J-Brine	630	15
03-Dec-10	9215	98227	JOS	WHT	Ralston, J.S. #3-150290	J-Brine	3150	75
03-Dec-10	9218	98230	JOS	WHT	Iseman #3H-158775 (M)	J-Mar-Brine	4536	108
03-Dec-10	9219	98231	JOS	WHT	Iseman #3H-158775 (M)	J-Mar-Brine	3780	90
03-Dec-10	9220	98232	JOS	WHT	Knapp #3-203350	J-Brine	3780	90
03-Dec-10	9222	98234	JOS	WHT	Barnett #5-155233	J-Brine	2856	68
03-Dec-10	9226	98238	JOS	WHT	Evanick #6H-154684 (M)	J-Mar-Brine	4620	110
03-Dec-10	9227	98239	JOS	WHT	Evanick #6H-154684 (M)	J-Mar-Brine	4620	110
06-Dec-10	9239	98251	JOS	GWS	R & P Coal (Stewart)-285828	J-Brine	2772	66
06-Dec-10	9249	98261	JOS	WHT	Evanick #6H-154684 (M)	J-Mar-Brine	4200	100
06-Dec-10	9250	98262	JOS	WHT	Biss, I. #1-203312	J-Brine	1890	45
06-Dec-10	9250	98262	JOS	WHT	Keith, R. #1-203346	J-Brine	1260	30
06-Dec-10	9254	98266	JOS	BUR	Silvis Compressor NP2478	J-Brine	1260	30
06-Dec-10	9254	98266	JOS	BUR	Trout, Ronald 001-151830	J-Brine	2100	50
06-Dec-10	9256	98268	JOS	GWS	Duquesne Nat. Gas #1-202357	J-Brine	3360	80
07-Dec-10	9278	98290	JOS	WHT	Hilliard F-29 #3-287788	J-Brine	3528	84
08-Dec-10	9286	98298	JOS	BUR	R & P Coal (Stewart)-285828	J-Brine	3360	80
08-Dec-10	9299	98311	JOS	BUR	R & P Coal (Stewart)-285828	J-Brine	3360	80
08-Dec-10	9301	98313	JOS	WHT	Yeany #1-287947	J-Brine	2940	70
08-Dec-10	9309	98321	JOS	WHT	Dougherty (90AC) #2-287968	J-Brine	1260	30
08-Dec-10	9309	98321	JOS	WHT	Shick F-36 #8-287922	J-Brine	1050	25
08-Dec-10	9309	98321	JOS	WHT	Shick F-36 #4-287902	J-Brine	1470	35
09-Dec-10	9335	98347	JOS	WHT	Moore #2-203362	J-Brine	3150	75
13-Dec-10	9431	98443	JOS	WHT	Iseman #3H-158775 (M)	J-Mar-Brine	3360	80
16-Dec-10	9529	98541	JOS	WHT	Lewis, E. #1-203354	J-Brine	1470	35
16-Dec-10	9529	98541	JOS	WHT	Bash #3-202987	J-Brine	1806	43
16-Dec-10	9536	98548	JOS	WHT	Foehrenbach, E. #1-203132	J-Brine	3066	73
16-Dec-10	19487	155405	FKL	A&A	Litke Unit P-4 #32H-159586 (M)	F-Mar-Brine	5000	119
16-Dec-10	19488	155406	FKL	A&A	Litke Unit P-4 #32H-159586 (M)	F-Mar-Brine	4200	100
16-Dec-10	19490	155407	FKL	A&A	Litke P-1 #15H-158803 (M)	F-Mar-Brine	4200	100

17-Dec-10	9540	98552	JOS	WHT	Clark, J.C. 001-202561	J-Brine	3360	80
20-Dec-10	9591	98603	JOS	WHT	Iseman #3H-158775 (M)	J-Mar-Brine	2520	60
20-Dec-10	9592	98604	JOS	WHT	Iseman #3H-158775 (M)	J-Mar-Brine	3360	80
20-Dec-10	11604	98616	JOS	WHT	Clark, J.C. 001-202561	J-Brine	2520	60
20-Dec-10	16006	155622	FKL	A&A	Litke Unit P-4 #32H-159586 (M)	F-Mar-Brine	4200	100
20-Dec-10	16006	155623	FKL	A&A	Litke Unit P-4 #32H-159586 (M)	F-Mar-Brine	4200	100
21-Dec-10	11634	98660	JOS	WHT	Kuzemchak, G. #2-155243	J-Brine	840	20
21-Dec-10	11634	98660	JOS	WHT	Kuzemchak, G. #4-155245	J-Brine	2520	60
21-Dec-10	15955	155704	FKL	A&A	Litke, P-1 #16H-159485 (M)	F-Mar-Brine	5400	129
21-Dec-10	15956	155703	FKL	A&A	Litke, P-1 #16H-159485 (M)	F-Mar-Brine	5400	129
22-Dec-10	11663	98675	JOS	WHT	Travis #1-287964	J-Brine	840	20
22-Dec-10	11663	98675	JOS	WHT	Travis #3-287966	J-Brine	2436	58
22-Dec-10	11663	98675	JOS	WHT	Shumaker #1-287970	J-Brine	924	22
22-Dec-10	11667	98679	JOS	WHT	Musser 58AC #1-287961	J-Brine	1890	45
22-Dec-10	11667	98679	JOS	WHT	Shumaker #1-287970	J-Brine	1218	29
22-Dec-10	11668	98680	JOS	WHT	McCracken, KJ 003-150980	J-Brine	1890	45
22-Dec-10	11668	98680	JOS	WHT	McCracken, KJ 004-150981	J-Brine	2310	55
22-Dec-10	16147	155798	FKL	A&A	Litke, P-1 #16H-159485 (M)	F-Mar-Brine	5400	129
23-Dec-10	11737	98739	JOS	A&A	Litke #8H (M)	J-Mar-Brine	4200	100
23-Dec-10	11738	98740	JOS	A&A	Litke #8H (M)	J-Mar-Brine	4900	117
23-Dec-10	11746	98751	JOS	WHT	Ralston, J.S. #3-150290	J-Brine	630	15
23-Dec-10	11746	98751	JOS	WHT	Ralston, J.S. #2-150289	J-Brine	2520	60
23-Dec-10	11751	98757	JOS	WHT	Bennett #8-150685	J-Brine	630	15
23-Dec-10	11751	98757	JOS	WHT	Bennett #6-150686	J-Brine	3150	75
23-Dec-10	11752	98758	JOS	WHT	Armstrong, C. #1-203309	J-Brine	4200	100
27-Dec-10	16291	155914	FKL	A&A	Litke P-1 #15H-158803 (M)	F-Mar-Frac	5500	131
27-Dec-10	16292	155916	FKL	A&A	Litke, P-1 #14H (M)	F-Mar-Brine	5400	129
28-Dec-10	10837	155997	FKL	A&A	Litke, P-1 #14H (M)	F-Mar-Brine	5400	129
28-Dec-10	11794	98802	JOS	WHT	Lockard, G. 002-203358	J-Brine	3780	90
28-Dec-10	11797	98806	JOS	WHT	Iseman #3H-158775 (M)	J-Mar-Brine	4880	116
28-Dec-10	11798	98807	JOS	WHT	Brown, Clair #1-202860	J-Brine	3780	90
28-Dec-10	16310	156022	FKL	A&A	Litke, P-1 #16H-159485 (M)	F-Mar-Frac	5500	131
29-Dec-10	10886	156083	FKL	A&A	Litke Unit P-4 #32H-159586 (M)	F-Mar-Brine	5400	129
29-Dec-10	11829	98839	JOS	WHT	St. Clair, R. #2-203180	J-Brine	1596	38
29-Dec-10	11829	98839	JOS	WHT	St. Clair, R. #3-203181	J-Brine	1722	41
29-Dec-10	16311	156105	FKL	A&A	Litke #31H-21609 (M)	F-Mar-Frac	5500	131
30-Dec-10	11857	98866	JOS	WHT	Kuzemchak, G. #4-155245	J-Brine	1890	45
30-Dec-10	11857	98866	JOS	WHT	Kuzemchak, G. #2-155243	J-Brine	1470	35
30-Dec-10	11858	98867	JOS	BUR	R & P Coal (Stewart)-285828	J-Brine	3360	80
30-Dec-10	16313	156177	FKL	MCK	Litke P-1 #15H-158803 (M)	F-Mar-Frac	5500	131
							241632	**5756**

PENNSYLVANIA BRINE TREATMENT, INC.

MIEKA LLC

1660 S. Stemmons Freeway, Suite #440, Lewisville, TX 75067

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
07-Dec-10	9277	98289	JOS	ROC	Schimizzi #1 (M)	J-Mar-Brine	4000	95
08-Dec-10	9287	98299	JOS	ROC	Schimizzi #1 (M)	J-Mar-Frac	4200	100
08-Dec-10	9296	98308	JOS	ROC	Schimizzi #1 (M)	J-Mar-Frac	4200	100
08-Dec-10	9307	98319	JOS	ROC	Schimizzi #1 (M)	J-Mar-Frac	4200	100
08-Dec-10	9316	98328	JOS	ROC	Schimizzi #1 (M)	J-Mar-Frac	4200	100
09-Dec-10	9329	98341	JOS	ROC	Schimizzi #1 (M)	J-Mar-Frac	4200	100
09-Dec-10	9336	98348	JOS	ROC	Schimizzi #1 (M)	J-Mar-Frac	4200	100
09-Dec-10	9345	98357	JOS	ROC	Schimizzi #1 (M)	J-Mar-Frac	4200	100
09-Dec-10	9353	98365	JOS	ROC	Schimizzi #1 (M)	J-Mar-Frac	4200	100
13-Dec-10	9408	98420	JOS	ROC	Schimizzi #1 (M)	J-Mar-Frac	1500	36
13-Dec-10	9414	98426	JOS	ROC	Schimizzi #1 (M)	J-Mar-Brine	4200	100
13-Dec-10	9422	98434	JOS	ROC	Schimizzi #1 (M)	J-Mar-Brine	4200	100
21-Dec-10	11633	98659	JOS	ROC	Schimizzi #1 (M)	J-Mar-Brine	4200	100
21-Dec-10	11648	98651	JOS	ROC	Schimizzi #1 (M)	J-Mar-Brine	3780	90
29-Dec-10	11816	98825	JOS	ROC	Schimizzi #1 (M)	J-Mar-Brine	4200	100
29-Dec-10	11826	98836	JOS	ROC	Schimizzi #1 (M)	J-Mar-Brine	4200	100
							3780	90
							63,460	1,511

PENNSYLVANIA BRINE TREATMENT, INC.

PA GENERAL ENERGY CORP.

120 Market Street, Warren, PA 16365

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
10-Dec-10	9375	98387	JOS	PDC	Mumau #1	J-Brine	3360	80
13-Dec-10	10351	155136	FKL	MCK	Fisk #2488 Pad B (M)	F-Mar-Brine	4620	110
13-Dec-10	10759	155133	FKL	MCK	Fisk #2488 Pad B (M)	F-Mar-Pit	2000	48
09-Dec-10	1924	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
09-Dec-10	1956	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Frac	4700	112
09-Dec-10	1957	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
09-Dec-10	1958	0	FKL	MAG	Fisk Hollow Pad A (M)	Port-Rail-Brine	4700	112
09-Dec-10	1959	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
09-Dec-10	1960		FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
09-Dec-10	1980	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
09-Dec-10	1981	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
09-Dec-10	1983	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
09-Dec-10	1984	0	FKL	MAG	#2145	Port-Rail-Pit	4700	112
09-Dec-10	1985	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
09-Dec-10	4231	0	FKL	NTI	#2145	Port-Rail-Pit	4700	112
09-Dec-10	60246	0	FKL	PGE	Pine Hill Pad A (M)	Port-Rail-Brine	4200	100
19-Dec-10	1938	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
19-Dec-10	1986	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
19-Dec-10	1990	0	FKL	MAG	#2145	Port-Rail-Pit	4700	112
19-Dec-10	1991	0	FKL	MAG	#2145	Port-Rail-Pit	4700	112
19-Dec-10	1992	0	FKL	MAG	Wharton #47013	Port-Rail-Brine	4700	112
19-Dec-10	1993	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
19-Dec-10	2020	0	FKL	MAG	#2145	Port-Rail-Pit	4700	112
19-Dec-10	2021	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
19-Dec-10	2022	0	FKL	MAG	#2145	Port-Rail-Pit	4700	112
19-Dec-10	2023	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
19-Dec-10	2025	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
19-Dec-10	2026	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
19-Dec-10	2027	0	FKL	MAG	Pine Hill Pad A (M)	Port-Rail-Brine	4700	112
							131680	3138

PENNSYLVANIA BRINE TREATMENT

REX ENERGY

476 Rolling Ridge Drive, Suite 300, State College, PA 16801

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
01-Dec-10	10009	154583	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
01-Dec-10	10109	154545	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
01-Dec-10	10114	154524	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
01-Dec-10	10115	154565	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
01-Dec-10	10265	154537	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
01-Dec-10	10281	154560	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
02-Dec-10	10012	154648	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
02-Dec-10	10110	154594	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
02-Dec-10	10116	154609	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
02-Dec-10	10117	154630	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
02-Dec-10	19519	154603	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
02-Dec-10	19544	154626	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
03-Dec-10	10011	154727	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
03-Dec-10	10118	154617	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
03-Dec-10	10119	154685	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
03-Dec-10	10120	154712	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
03-Dec-10	10301	154681	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
03-Dec-10	10401	154699	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
04-Dec-10	10121	154746	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
04-Dec-10	10122	154757	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
04-Dec-10	10123	154764	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
04-Dec-10	10302	154752	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
04-Dec-10	10308	154760	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
06-Dec-10	10124	154779	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
06-Dec-10	10125	154797	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
06-Dec-10	10126	154821	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
06-Dec-10	10303	154798	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
06-Dec-10	10343	154780	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
07-Dec-10	10304	154840	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
07-Dec-10	10305	154858	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
07-Dec-10	10307	154888	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
07-Dec-10	10393	154834	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
07-Dec-10	10394	154857	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130

07-Dec-10	10525	154886	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
08-Dec-10	10306	154896	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
08-Dec-10	10395	154927	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
08-Dec-10	10396	154961	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
08-Dec-10	10400	154899	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
08-Dec-10	10526	154947	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
08-Dec-10	10563	154917	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
09-Dec-10	10397	154993	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
09-Dec-10	10398	155011	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
09-Dec-10	10399	154962	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
09-Dec-10	10527	155007	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
09-Dec-10	10528	155016	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
09-Dec-10	10585	154969	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
09-Dec-10	10604	154988	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
09-Dec-10	10622	155018	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
10-Dec-10	10529	155051	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
10-Dec-10	10606	155047	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
10-Dec-10	10645	155030	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
10-Dec-10	10647	155035	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
11-Dec-10	10533	155103	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
11-Dec-10	10607	155089	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
11-Dec-10	10608	155096	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
11-Dec-10	10714	155093	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
13-Dec-10	10609	155175	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
13-Dec-10	10610	155193	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
13-Dec-10	10621	155127	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
13-Dec-10	10756	155131	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
13-Dec-10	10767	155149	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
13-Dec-10	10771	155156	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
13-Dec-10	19401	155182	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
14-Dec-10	10530	155197	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
14-Dec-10	10531	155228	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
14-Dec-10	10532	155247	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
14-Dec-10	10611	155199	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
14-Dec-10	10612	155251	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
14-Dec-10	19451	155233	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
15-Dec-10	10613	155294	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
15-Dec-10	10614	155316	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
15-Dec-10	10615	155333	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
15-Dec-10	19407	155287	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
15-Dec-10	19409	155308	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
15-Dec-10	19410	155324	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130

16-Dec-10	10616	155350	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
16-Dec-10	10617	155383	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
16-Dec-10	10618	155416	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
16-Dec-10	10619	155431	FKL	D&D	nauff, R. Unit #1H-05999 (M	F-Mar-Frac	5460	130
16-Dec-10	19412	155355	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
16-Dec-10	19413	155391	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
16-Dec-10	19414	155418	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
16-Dec-10	19415	155435	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
17-Dec-10	10620	155447	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
17-Dec-10	15720	155489	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
17-Dec-10	15721	155510	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
17-Dec-10	19416	155460	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
17-Dec-10	19417	155445	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
18-Dec-10	15722	155540	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
18-Dec-10	15723	155519	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
18-Dec-10	15861	155535	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
18-Dec-10	15889	155545	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
19-Dec-10	15724	155581	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
19-Dec-10	15725	155579	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
19-Dec-10	15896	155578	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
19-Dec-10	15922	155580	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
20-Dec-10	15726	155599	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
20-Dec-10	15727	155629	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
20-Dec-10	15728	155656	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
20-Dec-10	15890	155583	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
20-Dec-10	15891	155615	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
20-Dec-10	15897	155582	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
21-Dec-10	15729	155694	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
21-Dec-10	15730	155692	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
21-Dec-10	15731	155733	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
21-Dec-10	15895	155739	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
22-Dec-10	11684	98690	JOS	D&D	Knauff Impoundment (M)	J-Mar-Frac	5460	130
22-Dec-10	15732	155759	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
22-Dec-10	15733	155771	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
22-Dec-10	15892	155758	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
22-Dec-10	15893	155765	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
22-Dec-10	15894	155796	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
22-Dec-10	16027	155813	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
22-Dec-10	16028	98694	JOS	D&D	Knauff Impoundment (M)	J-Mar-Frac	5460	130
23-Dec-10	11701	98697	JOS	D&D	Knauff Impoundment (M)	J-Mar-Frac	5460	130
23-Dec-10	16029	98709	JOS	D&D	Knauff Impoundment (M)	J-Mar-Frac	5460	130
27-Dec-10	11774	98781	JOS	D&D	Knauff Impoundment (M)	J-Mar-Frac	5460	130

27-Dec-10	16030	155897	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
27-Dec-10	16031	155938	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
27-Dec-10	16257	155896	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
27-Dec-10	16258	155918	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
27-Dec-10	16259	98786	JOS	D&D	Knauff Impoundment (M)	J-Mar-Frac	5460	130
27-Dec-10	16279	155946	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
28-Dec-10	16032	155961	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
28-Dec-10	16033	155979	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
28-Dec-10	16035	98803	JOS	D&D	Knauff Impoundment (M)	J-Mar-Frac	5460	130
28-Dec-10	16260	155993	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
28-Dec-10	16261	156038	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
28-Dec-10	16266	156044	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
28-Dec-10	16267	155968	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
29-Dec-10	16034	156107	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
29-Dec-10	16036	156061	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
29-Dec-10	16037	98830	JOS	D&D	Knauff Impoundment (M)	J-Mar-Frac	5460	130
29-Dec-10	16038	156118	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
29-Dec-10	16262	156051	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
29-Dec-10	16263	156087	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
29-Dec-10	16278	156091	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
30-Dec-10	10864	156126	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
30-Dec-10	10865	156135	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
30-Dec-10	16264	156125	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
30-Dec-10	16265	156131	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
30-Dec-10	16268	156148	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
30-Dec-10	16371	156153	FKL	D&D	Knauff Impoundment (M)	F-Mar-Frac	5460	130
							780780	**18590**

PENNSYLVANIA BRINE TREATMENT, INC.

RICE ENERGY, LP

171 Hillpointe Drive Ste. #301, Canonsburg, PA 15317

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
01-Dec-10	9121	98133	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3750	89
01-Dec-10	9153	98165	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3750	89
02-Dec-10	9185	98197	JOS	HAR	X-Man #1 (M)	J-Mar-Brine	3750	89
08-Dec-10	9297	98309	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3750	89
13-Dec-10	9416	98428	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
15-Dec-10	9495	98507	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
16-Dec-10	9515	98527	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
16-Dec-10	9531	98543	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
20-Dec-10	9584	98596	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
20-Dec-10	9599	98611	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
21-Dec-10	11608	98620	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
21-Dec-10	11613	98625	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
21-Dec-10	11630	98642	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
21-Dec-10	11635	98661	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
22-Dec-10	11660	98672	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
29-Dec-10	11822	98832	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
29-Dec-10	11833	98843	JOS	WOT	X-Man #1 (M)	J-Mar-Brine	3570	85
							61,410	1,461

PENNSYLVANIA BRINE TREATMENT, INC.

SAMSON RESOURCES COMPANY

P.O. Box 21022, Tulsa, OK 74121

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
01-Dec-10	9119	98131	JOS	STU	Menhorn #2H (M)	J-Mar-Brine	4869	116
21-Dec-10	11609	98621	JOS	STU	Menhorn #2H (M)	J-Mar-Brine	4869	116
							9738	232

PENNSYLVANIA BRINE TREATMENT

STONE ENERGY

P.O. Box 52807, Lafayette, LA 70505

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
04-Dec-10	15421	154766	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Pit	4650	111
06-Dec-10	10348	154790	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Pit	4620	110
21-Dec-10	3312	155750	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5000	119
21-Dec-10	15422	155731	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5000	119
21-Dec-10	16122	155753	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
22-Dec-10	3313	155804	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5000	119
22-Dec-10	3314	98695	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	5500	131
22-Dec-10	3316	155807	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5000	119
22-Dec-10	3319	98693	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	5460	130
22-Dec-10	3322	98691	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	5500	131
22-Dec-10	11670	98682	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	4200	100
22-Dec-10	11671	98683	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	3800	90
22-Dec-10	11677	98689	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	3800	90
22-Dec-10	11678	98692	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	4200	100
22-Dec-10	11685	98696	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	5460	130
23-Dec-10	3282	98727	JOS	KEI	Ashbaugh Unit #1H (M)	J-Mar-Frac	3860	92
23-Dec-10	3317	98730	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	5460	130
23-Dec-10	3320	98699	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	5460	130
23-Dec-10	11679	98698	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	5500	131
23-Dec-10	11680	155886	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
23-Dec-10	11681	155874	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
23-Dec-10	11686	98702	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	5500	131
23-Dec-10	11694	98701	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	5460	130
23-Dec-10	11702	98710	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	4200	100
23-Dec-10	11722	155885	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
23-Dec-10	11730	98747	JOS	KEI	Ashbaugh Unit #1H (M)	J-Mar-Frac	4200	100
23-Dec-10	15991	155852	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	3800	90
23-Dec-10	16195	155845	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	3800	90
23-Dec-10	16199	155848	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	4200	100
23-Dec-10	16248	155887	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
27-Dec-10	3321	155944	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
27-Dec-10	10352	155932	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
27-Dec-10	11687	155949	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
27-Dec-10	11692	155951	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
27-Dec-10	11723	98775	JOS	MCK	Ashbaugh Unit #1H (M)	J-Mar-Frac	5460	130
27-Dec-10	11724	155933	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
27-Dec-10	11731	155892	FKL	KEI	Ashbaugh Unit #1H (M)	F-Mar-Frac	4200	100
27-Dec-10	11732	155937	FKL	KEI	Ashbaugh Unit #1H (M)	F-Mar-Frac	4200	100
27-Dec-10	11733	155913	FKL	KEI	Ashbaugh Unit #1H (M)	F-Mar-Frac	4200	100
27-Dec-10	16286	155909	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Pit	6300	150

27-Dec-10	16287	155910	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Frac	6300	150
27-Dec-10	16288	155911	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Pit	5200	124
27-Dec-10	16289	155912	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Pit	5500	131
27-Dec-10	16290	155915	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Pit	5500	131
27-Dec-10	16301	155941	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
27-Dec-10	16322	155942	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5000	119
27-Dec-10	16323	155950	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
28-Dec-10	10802	155985	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	10803	155984	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	4620	110
28-Dec-10	10805	156007	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	4620	110
28-Dec-10	10809	156021	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	4620	110
28-Dec-10	10812	156010	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	10813	156024	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	10814	156037	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	10826	156009	FKL	KEI	Ashbaugh Unit #1H (M)	F-Mar-Frac	4200	100
28-Dec-10	10830	155988	FKL	E.C	Ashbaugh Unit #1H (M)	F-Mar-Frac	4620	110
28-Dec-10	10831	155989	FKL	E.C	Ashbaugh Unit #1H (M)	F-Mar-Frac	6300	150
28-Dec-10	10832	155990	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Pit	6300	150
28-Dec-10	10833	155991	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Pit	6300	150
28-Dec-10	10834	155994	FKL	E.C	Ashbaugh Unit #1H (M)	F-Mar-Frac	6300	150
28-Dec-10	10835	155995	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Frac	5000	119
28-Dec-10	10836	155996	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
28-Dec-10	10838	155998	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Pit	5400	129
28-Dec-10	10841	156011	FKL	E.C	Ashbaugh Unit #1H (M)	F-Mar-Frac	4260	101
28-Dec-10	10847	156033	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	4620	110
28-Dec-10	10848	156035	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5000	119
28-Dec-10	10849	156043	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	11690	155957	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	11691	155953	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	11734	155986	FKL	KEI	Ashbaugh Unit #1H (M)	F-Mar-Frac	4200	100
28-Dec-10	16302	156006	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	16303	156020	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	16304	156036	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	16324	156008	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
28-Dec-10	16325	156023	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
28-Dec-10	16326	156034	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
28-Dec-10	16327	156040	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
28-Dec-10	16343	155952	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
28-Dec-10	16344	155956	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
28-Dec-10	16345	155962	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
28-Dec-10	16346	155967	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
28-Dec-10	16354	155955	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	16355	156039	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	16356	156042	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	16370	155960	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	16379	155964	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	16382	155972	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
28-Dec-10	16383	155974	FKL	E.C	Ashbaugh Unit #1H (M)	F-Mar-Frac	4620	110
28-Dec-10	16384	155973	FKL	E.C	Ashbaugh Unit #1H (M)	F-Mar-Frac	4620	110

28-Dec-10	16385	155975	FKL	E.C	Ashbaugh Unit #1H (M)	F-Mar-Frac	4200	100
29-Dec-10	10827	156089	FKL	KEI	Ashbaugh Unit #1H (M)	F-Mar-Frac	4200	100
29-Dec-10	10828	156100	FKL	KEI	Ashbaugh Unit #1H (M)	F-Mar-Frac	4200	100
29-Dec-10	10829	156108	FKL	KEI	Ashbaugh Unit #1H (M)	F-Mar-Frac	4200	100
29-Dec-10	10850	156046	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
29-Dec-10	10852	156050	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
29-Dec-10	10853	156120	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
29-Dec-10	10858	156055	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
29-Dec-10	10862	156063	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
29-Dec-10	10863	156090	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
29-Dec-10	10880	156078	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Pit	5400	129
29-Dec-10	10881	156077	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Pit	6300	150
29-Dec-10	10882	156076	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Pit	6300	150
29-Dec-10	10883	156079	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Pit	6300	150
29-Dec-10	10884	156081	FKL	RNI	Ashbaugh Unit #1H (M)	F-Mar-Frac	5400	129
29-Dec-10	11688	156053	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
29-Dec-10	11689	156062	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
29-Dec-10	11735	156073	FKL	KEI	Ashbaugh Unit #1H (M)	F-Mar-Frac	4200	100
29-Dec-10	16305	156102	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
29-Dec-10	16306	156116	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
29-Dec-10	16312	156115	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
29-Dec-10	16328	156088	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
29-Dec-10	16329	156101	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
29-Dec-10	16330	156117	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
29-Dec-10	16347	156049	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
29-Dec-10	16357	156045	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
29-Dec-10	16358	156047	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
29-Dec-10	16359	156052	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
29-Dec-10	16360	156056	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
30-Dec-10	10353	156147	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	4620	110
30-Dec-10	10806	156174	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	4620	110
30-Dec-10	10815	156163	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
30-Dec-10	10854	156121	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
30-Dec-10	10855	156124	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
30-Dec-10	10856	156129	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
30-Dec-10	10946	156150	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	4620	110
30-Dec-10	10947	156151	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
30-Dec-10	10948	156156	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	4620	110
30-Dec-10	10967	156176	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
30-Dec-10	10969	156180	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	4620	110
30-Dec-10	10971	156182	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
30-Dec-10	16307	156149	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
30-Dec-10	16308	156154	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
30-Dec-10	16309	156173	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5460	130
30-Dec-10	16348	156134	FKL	MCK	Ashbaugh Unit #1H (M)	F-Mar-Frac	5500	131
							696790	16591

RECEIVED

JAN 28 2011

DEP, SOUTHWEST REGION
OIL & GAS

PENNSYLVANIA BRINE TREATMENT, INC.

XTO ENERGY

395 Airport Road, Indiana, PA 15701

Manifest Date	Manifest #	Sample #	Plant	Transport Code	Well Name	Material Type	Gallons	Barrels
01-Dec-10	9124	98136	JOS	MUL	Homer City Power Plant #4H-8421H-303004 (M)	J-Mar-Brine	3024	72
01-Dec-10	9127	98139	JOS	MUL	Forsha, Minta #1-6017-300379	J-Brine	2940	70
01-Dec-10	9137	98149	JOS	MUL	Flickinger #8447H-303082 (M)	J-Mar-Brine	3780	90
01-Dec-10	9145	98157	JOS	MUL	C.B.C. #1-6003-300244	J-Brine	2940	70
01-Dec-10	9149	98161	JOS	MUL	Forsha, Minta #1-6017-300379	J-Brine	3108	74
01-Dec-10	9155	98167	JOS	MUL	Buterbaugh, R. #4-7353-300241	J-Brine	3360	80
02-Dec-10	9168	98180	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	2940	70
02-Dec-10	9179	98191	JOS	MUL	Hill, Larry #1-6025-300480	J-Brine	2940	70
02-Dec-10	9192	98204	JOS	MUL	Mumau, L. #1-7358-300737	J-Brine	2520	60
02-Dec-10	9192	98204	JOS	MUL	Hill, D.J. #1-7356-300479	J-Brine	840	20
02-Dec-10	19547	154629	FKL	C.T	Temple #8496H-303113 (M)	F-Mar-Brine	5500	131
02-Dec-10	19564	154639	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	5500	131
02-Dec-10	77137	154633	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	5500	131
03-Dec-10	9197	98209	JOS	MUL	Indiana Airport-8431H-302910 (M)	J-Mar-Brine	2940	70
03-Dec-10	9212	98224	JOS	MUL	Flickinger #8447H-303082 (M)	J-Mar-Brine	3780	90
03-Dec-10	9213	98225	JOS	MUL	Hanwell, Richard #1-6022-300453	J-Brine	2940	70
03-Dec-10	9217	98229	JOS	MUL	Sides, Uriah #1-6041-300914	J-Brine	2940	70
03-Dec-10	9221	98233	JOS	MUL	Homer City Power Plant #4H-8421H-303004 (M)	J-Mar-Brine	2940	70
03-Dec-10	9228	98240	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	3360	80
03-Dec-10	10409	154709	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	5500	131
04-Dec-10	77024	154762	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	4200	100
04-Dec-10	77025	154761	FKL	C.T	Temple #8496H-303113 (M)	F-Mar-Brine	4200	100
06-Dec-10	9235	98247	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	2940	70
06-Dec-10	9236	98248	JOS	MUL	C.B.C. #6-6008-300249	J-Brine	3780	90
06-Dec-10	9244	98256	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	2940	70
06-Dec-10	9246	98258	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	3780	90
06-Dec-10	9247	98259	JOS	MUL	Homercity Power Plant-8422H-303005 (M)	J-Mar-Brine	2940	70
06-Dec-10	9251	98263	JOS	MUL	Homer City Power Plant #4H-8421H-303004 (M)	J-Mar-Brine	3780	90
06-Dec-10	10357	154800	FKL	C.T	Marquardt #8494H-303111 (M)	F-Mar-Brine	5000	119
06-Dec-10	77135	154792	FKL	C.T	Temple #8496H-303113 (M)	F-Mar-Frac	5500	131
06-Dec-10	77308	154793	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	5500	131
07-Dec-10	9265	98277	JOS	MUL	Indiana Airport-8431H-302910 (M)	J-Mar-Brine	3780	90
07-Dec-10	9266	98278	JOS	MUL	Homer City Power Plant #4H-8421H-303004 (M)	J-Mar-Brine	2940	70
07-Dec-10	9268	98280	JOS	MUL	Flickinger #8447H-303082 (M)	J-Mar-Brine	2940	70
07-Dec-10	9276	98287	JOS	MUL	Pantall, J. #3-7214-300796	J-Brine	3360	80
07-Dec-10	10515	154865	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	5500	131
07-Dec-10	10516	154868	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Frac	5500	131
08-Dec-10	2844	154937	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	4500	107
08-Dec-10	2850	154949	FKL	C.T	Temple #8496H-303113 (M)	F-Mar-Frac	5500	131
08-Dec-10	9285	98297	JOS	MUL	Indiana Airport-8431H-302910 (M)	J-Mar-Brine	2940	70
08-Dec-10	9290	98302	JOS	K.V	Laurel Ridge State Park #1-6030-300572	J-Brine	3738	89
08-Dec-10	9291	98303	JOS	MUL	Flickinger #8447H-303082 (M)	J-Mar-Brine	2940	70
08-Dec-10	9305	98317	JOS	MUL	Vehovic #2-6048-301007	J-Brine	2940	70

08-Dec-10	9314	98326	JOS	MUL	Bloom #8315-300188 (M)	J-Mar-Brine	2940	70
09-Dec-10	2902	155012	FKL	C.T	Marquardt #8494H-303111 (M)	F-Mar-Brine	5000	119
09-Dec-10	9333	98345	JOS	MUL	Savasta, Guy M. #1-7365-300895	J-Brine	3360	80
09-Dec-10	9340	98352	JOS	MUL	Homer City Power Plant #4H-8421H-303004 (M)	J-Mar-Brine	2940	70
09-Dec-10	9355	98367	JOS	MUL	Sides, Uriah #1-6041-300914	J-Brine	2940	70
09-Dec-10	9360	98372	JOS	MUL	Schroth, Walter #1-6040-300900	J-Brine	2940	70
09-Dec-10	9363	98375	JOS	MUL	C.B.C. #1-6003-300244	J-Brine	2940	70
09-Dec-10	9365	98377	JOS	MUL	Flickinger #8447H-303082 (M)	J-Mar-Brine	2940	70
10-Dec-10	9374	98386	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	2940	70
10-Dec-10	9395	98407	JOS	MUL	Homercity Power Plant-8422H-303005 (M)	J-Mar-Brine	3108	74
10-Dec-10	9400	98412	JOS	MUL	C.B.C. #3-6005-300246	J-Brine	2940	70
10-Dec-10	10673	155069	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	5500	131
10-Dec-10	77134	155068	FKL	C.T	Temple #8496H-303113 (M)	F-Mar-Brine	5500	131
13-Dec-10	2864	155176	FKL	C.T	Marquardt #8537H-303221 (M)	F-Mar-Brine	5000	119
13-Dec-10	9406	98418	JOS	MUL	Homer City Power Plant #4H-8421H-303004 (M)	J-Mar-Brine	3024	72
13-Dec-10	9410	98422	JOS	MUL	C.B.C. #3-6005-300246	J-Brine	2940	70
13-Dec-10	9417	98429	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	2940	70
13-Dec-10	9423	98435	JOS	MUL	Laney, Marlin #1-6029-300571	J-Brine	2940	70
13-Dec-10	9424	98437	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	2940	70
13-Dec-10	9425	98436	JOS	MUL	Indiana Airport-8431H-302910 (M)	J-Mar-Brine	2940	70
13-Dec-10	10769	155152	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	5500	131
13-Dec-10	10777	155168	FKL	C.T	Temple #8496H-303113 (M)	F-Mar-Brine	5500	131
13-Dec-10	77066	155154	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	6000	143
14-Dec-10	2865	155259	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	5000	119
14-Dec-10	9436	98448	JOS	MUL	Indiana Airport-8431H-302910 (M)	J-Mar-Brine	2940	70
14-Dec-10	9441	98453	JOS	MUL	Flickinger #8447H-303082 (M)	J-Mar-Brine	3780	90
14-Dec-10	9443	98455	JOS	MUL	Homer City Power Plant #4H-8421H-303004 (M)	J-Mar-Brine	3024	72
14-Dec-10	9449	98461	JOS	MUL	Indiana Airport-8431H-302910 (M)	J-Mar-Brine	2940	70
14-Dec-10	77190	155257	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	5500	131
14-Dec-10	77191	155258	FKL	C.T	Temple #8496H-303113 (M)	F-Mar-Brine	5500	131
15-Dec-10	9471	98483	JOS	MUL	Hill, Larry #1-6025-300460	J-Brine	2940	70
15-Dec-10	9472	98484	JOS	MUL	McHenry, D.F. #3-7202-300692	J-Brine	3066	73
15-Dec-10	9475	98487	JOS	MUL	Hanwell, Richard #1-6022-300453	J-Brine	3780	90
15-Dec-10	9498	98510	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	2940	70
07-Dec-10	2760	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Frac	4200	100
07-Dec-10	3115	0	FKL	C.T	Marquardt #8517H-303189 (M)	NB-Rail-Frac	5000	119
07-Dec-10	3116	0	FKL	C.T	Marquardt #8517H-303189 (M)	NB-Rail-Frac	2400	57
07-Dec-10	3117	0	FKL	C.T	Marquardt #8517H-303189 (M)	NB-Rail-Frac	2600	62
07-Dec-10	3118	0	FKL	C.T	Marquardt #8494H-303111 (M)	NB-Rail-Brine	5000	119
07-Dec-10	3119	0	FKL	C.T	Temple #8496H-303113 (M)	NB-Rail-Brine	4200	100
07-Dec-10	3122	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	5000	119
07-Dec-10	3123	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	4200	100
07-Dec-10	3124	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Frac	5000	119
07-Dec-10	3125	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	4200	100
07-Dec-10	3126	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	5000	119
07-Dec-10	77036	0	FKL	C.T	Temple #8496H-303113 (M)	NB-Rail-Brine	5500	131
07-Dec-10	77037	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	5500	131
07-Dec-10	77103	0	FKL	C.T	Marquardt #8494H-303111 (M)	NB-Rail-Brine	3500	83
07-Dec-10	77104	0	FKL	C.T	Marquardt #8517H-303189 (M)	NB-Rail-Frac	4200	100
07-Dec-10	77105		FKL	C.T	Marquardt #8517H-303189 (M)	NB-Rail-Frac	4200	100

08-Dec-10	2827	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	5000	119
08-Dec-10	2829	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	4200	100
08-Dec-10	3120	0	FKL	C.T	Temple #8496H-303113 (M)	NB-Rail-Brine	4000	95
08-Dec-10	3121	0	FKL	C.T	Temple #8496H-303113 (M)	NB-Rail-Brine	1000	24
08-Dec-10	77018	0	FKL	C.T	Temple #8496H-303113 (M)	NB-Rail-Brine	1100	26
08-Dec-10	77019	0	FKL	C.T	Marquardt #8537H-303221 (M)	NB-Rail-Brine	4200	100
08-Dec-10	77020	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	4200	100
08-Dec-10	77021	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	4200	100
08-Dec-10	77022	0	FKL	C.T	Temple #8496H-303113 (M)	NB-Rail-Brine	4200	100
08-Dec-10	77023	0	FKL	C.T	Temple #8496H-303113 (M)	NB-Rail-Brine	4200	100
08-Dec-10	77041	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	4200	100
08-Dec-10	77074	0	FKL	C.T	Marquardt #8537H-303221 (M)	NB-Rail-Brine	2100	50
08-Dec-10	77075	0	FKL	C.T	Marquardt #8537H-303221 (M)	NB-Rail-Brine	4200	100
08-Dec-10	77076	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	4200	100
08-Dec-10	77077	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	2100	50
08-Dec-10	77100	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	4200	100
08-Dec-10	77101	0	FKL	C.T	Temple #8496H-303113 (M)	NB-Rail-Brine	4200	65
08-Dec-10	77102	0	FKL	C.T	Temple #8541H-303225 (M)	NB-Rail-Brine	1000	24
16-Dec-10	9513	98525	JOS	MUL	Flickinger #8447H-303082 (M)	J-Mar-Brine	2940	70
16-Dec-10	9524	98536	JOS	MUL	C.B.C. #1-6003-300244	J-Brine	2940	70
16-Dec-10	9537	98549	JOS	MUL	Forsha, Minta #1-6017-300379	J-Brine	2940	70
16-Dec-10	77131	155415	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	5500	131
17-Dec-10	9549	98561	JOS	MUL	Indiana Airport-8431H-302910 (M)	J-Mar-Brine	2898	69
17-Dec-10	9558	98570	JOS	MUL	Dunlap, Melissa #1-6015-300356	J-Brine	2940	70
17-Dec-10	9562	98574	JOS	MUL	Sides, Uriah #1-6041-300914	J-Brine	2940	70
18-Dec-10	9564	98576	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	2940	70
18-Dec-10	9566	98578	JOS	MUL	Flickinger #8447H-303082 (M)	J-Mar-Brine	2940	70
20-Dec-10	9569	98581	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	2940	70
20-Dec-10	9581	98593	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	3780	90
20-Dec-10	9588	98600	JOS	MUL	Kauffman #4-8210-300533	J-Brine	4200	100
20-Dec-10	9594	98606	JOS	MUL	Rice, F. #1 (30AC)-7362-300854	J-Brine	3150	75
20-Dec-10	9595	98607	JOS	MUL	Homer City Power Plant #4H-8421H-303004 (M)	J-Mar-Brine	3024	72
20-Dec-10	11601	98613	JOS	MUL	C.B.C. #3-6005-300246	J-Brine	3780	90
21-Dec-10	11612	98624	JOS	MUL	Indiana Airport-8431H-302910 (M)	J-Mar-Brine	3780	90
21-Dec-10	11615	98627	JOS	MUL	Flickinger #8447H-303082 (M)	J-Mar-Brine	3780	90
21-Dec-10	11621	98633	JOS	MUL	C.B.C. #4-6006-300247	J-Brine	2940	70
21-Dec-10	11621	98633	JOS	MUL	C.B.C. #3-6005-300246	J-Brine	840	20
21-Dec-10	11629	98641	JOS	MUL	Rhoads, P.F. #1-7220-300847	J-Brine	2184	52
21-Dec-10	11629	98641	JOS	MUL	Blue Spruce Park #1-7258-300189	J-Brine	1596	38
21-Dec-10	11645	98648	JOS	MUL	Homer City Power Plant #4H-8421H-303004 (M)	J-Mar-Brine	3780	90
21-Dec-10	11655	98658	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	3780	90
22-Dec-10	11641	98667	JOS	MUL	Joiner, C. #1-6027-300528	J-Brine	3780	90
22-Dec-10	11656	98668	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	3780	90
22-Dec-10	11669	98681	JOS	MUL	McKee-6058-300710	J-Brine	1764	42
22-Dec-10	11669	98681	JOS	MUL	White, Harry-8402-301039	J-Brine	1596	38
23-Dec-10	11698	98706	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	3780	90
23-Dec-10	11703	98711	JOS	MUL	Sides, Uriah #1-6041-300914	J-Brine	3360	80
23-Dec-10	11708	98716	JOS	MUL	Hanwell, Richard #1-6022-300453	J-Brine	3780	90
23-Dec-10	11719	98728	JOS	MUL	C.B.C. #3-6005-300246	J-Brine	3360	80
23-Dec-10	11728	98734	JOS	MUL	Homer City Power Plant #4H-8421H-303004 (M)	J-Mar-Brine	3360	80

27-Dec-10	11756	98762	JOS	MUL	Flickinger #8447H-303082 (M)	J-Mar-Brine	2940	70
27-Dec-10	11758	98764	JOS	MUL	Indiana Airport-8431H-302910 (M)	J-Mar-Brine	3780	90
27-Dec-10	11763	98769	JOS	MUL	Homer City Power Plant #4H-8421H-303004 (M)	J-Mar-Brine	3780	90
27-Dec-10	11769	98776	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	3780	90
27-Dec-10	11776	98783	JOS	MUL	Homercity Power Plant-8422H-303005 (M)	J-Mar-Brine	3780	90
27-Dec-10	11784	98792	JOS	MUL	Flickinger #8447H-303082 (M)	J-Mar-Brine	2940	70
28-Dec-10	11785	98793	JOS	MUL	Indiana Airport-8431H-302910 (M)	J-Mar-Brine	2940	70
28-Dec-10	11786	98796	JOS	MUL	C.B.C. #3-6005-300246	J-Brine	840	20
28-Dec-10	11788	98798	JOS	MUL	C.B.C. #1-6003-300244	J-Brine	2940	70
28-Dec-10	11792	98800	JOS	MUL	Homercity Power Plant-8422H-303005 (M)	J-Mar-Brine	3108	74
28-Dec-10	11795	98804	JOS	MUL	McHenry, D.F. #1-7200-300690	J-Brine	840	20
28-Dec-10	11795	98804	JOS	MUL	Getty, S.W. -8259-300404	J-Brine	3360	80
28-Dec-10	11799	98808	JOS	MUL	Forsha, Minta #1-6017-300379	J-Brine	3780	90
29-Dec-10	11808	98817	JOS	MUL	Indiana Airport-8431H-302910 (M)	J-Mar-Brine	2940	70
29-Dec-10	11812	98821	JOS	MUL	Williams, Benton #1-6050-301063	J-Brine	3780	90
29-Dec-10	11814	98823	JOS	MUL	Bloom #8314-300187	J-Brine	2646	63
29-Dec-10	11814	98823	JOS	MUL	Bloom #8315-300188 (M)	J-Mar-Brine	714	17
30-Dec-10	10907	156122	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	5500	131
30-Dec-10	10949	156159	FKL	C.T	Temple #8541H-303225 (M)	F-Mar-Brine	5500	131
30-Dec-10	11842	98851	JOS	MUL	Homer City Power Plant #4H-8421H-303004 (M)	J-Mar-Brine	3780	90
30-Dec-10	11844	98853	JOS	MUL	Hanwell, Richard #1-6022-300453	J-Brine	2940	70
30-Dec-10	11860	98869	JOS	MUL	Flickinger #8447H-303082 (M)	J-Mar-Brine	3780	90
30-Dec-10	77524	156123	FKL	C.T	Temple #8496H-303113 (M)	F-Mar-Frac	5500	131
							596732	14173

Radioactive Wastewater From Fracking Is Found in a Pennsylvania Stream

http://blogs.smithsonianmag.com/science/2013/10/radioactive-wastewater-from-fracking-is-found-in-a-pennsylvania-stream/#ixzz2gaB8X86f

October 2, 2013

Radioactive Wastewater From Fracking Is Found in a Pennsylvania Stream

New testing of treated wastewater from fracking shows that it contains high levels of radioactive radium, along with chloride and bromide. Image via Environmental Science and Technology/Warner et. al.

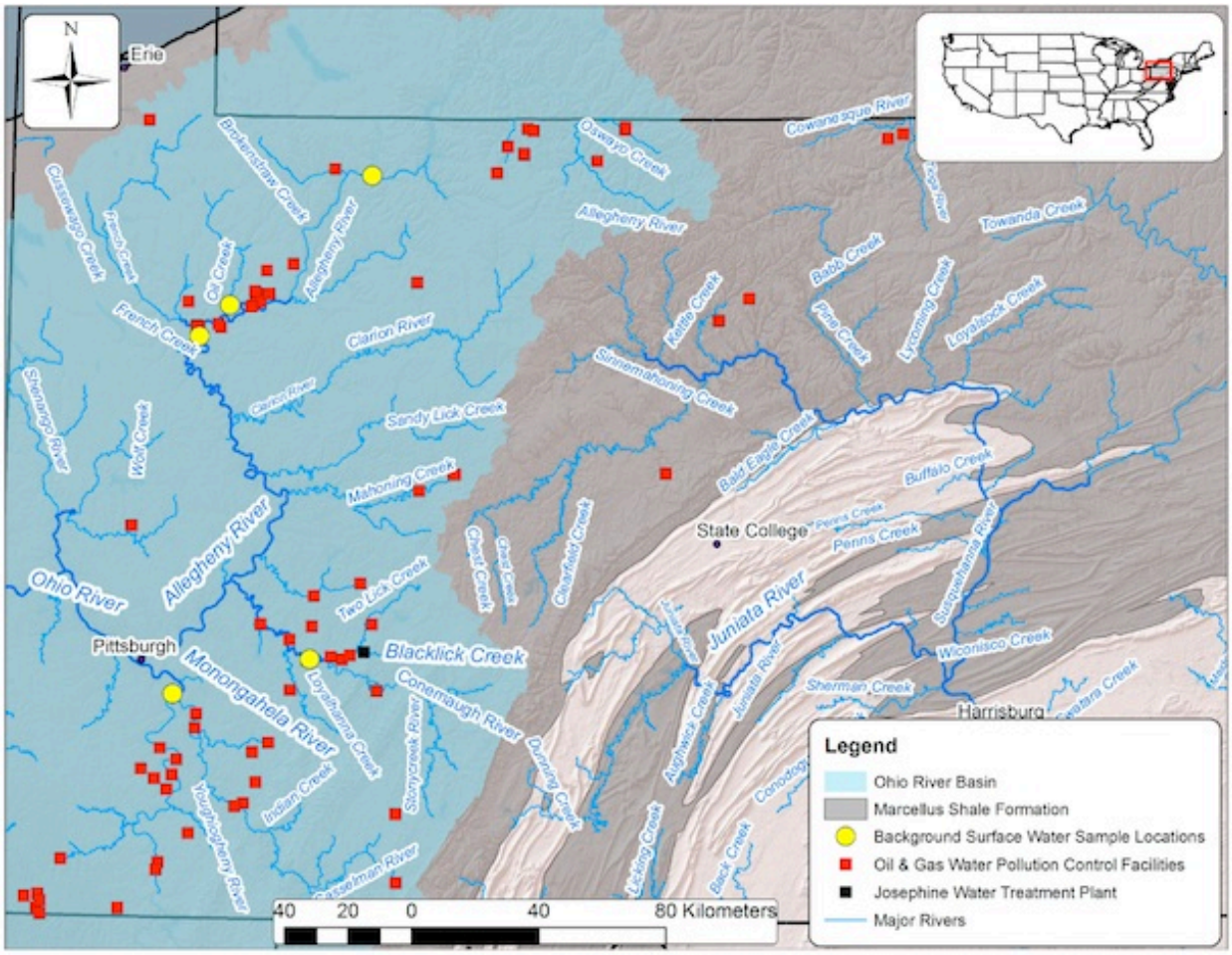
In the state of Pennsylvania, home to the lucrative Marcellus Shale formation, 74 facilities treat wastewater from the process of hydraulic fracturing (a.k.a. "fracking") for natural gas and release it into streams. There's no national set of standards that guides this treatment process—the EPA notes that the Clean

Water Act's guidelines were developed before fracking even existed, and that many of the processing plants "are not properly equipped to treat this type of wastewater"—and scientists have conducted relatively little assessment of the wastewater to ensure it's safe after being treated.

Recently, a group of Duke University scientists decided to do some testing. They contacted the owners of one treatment plant, the Josephine Brine Treatment Facility on Blacklick Creek in Indiana County, Pennsylvania, but, "when we tried to work with them, it was very difficult getting ahold of the right person," says Avner Vengosh, an Earth scientist from Duke. "Eventually, we just went and tested water right from a public area downstream."

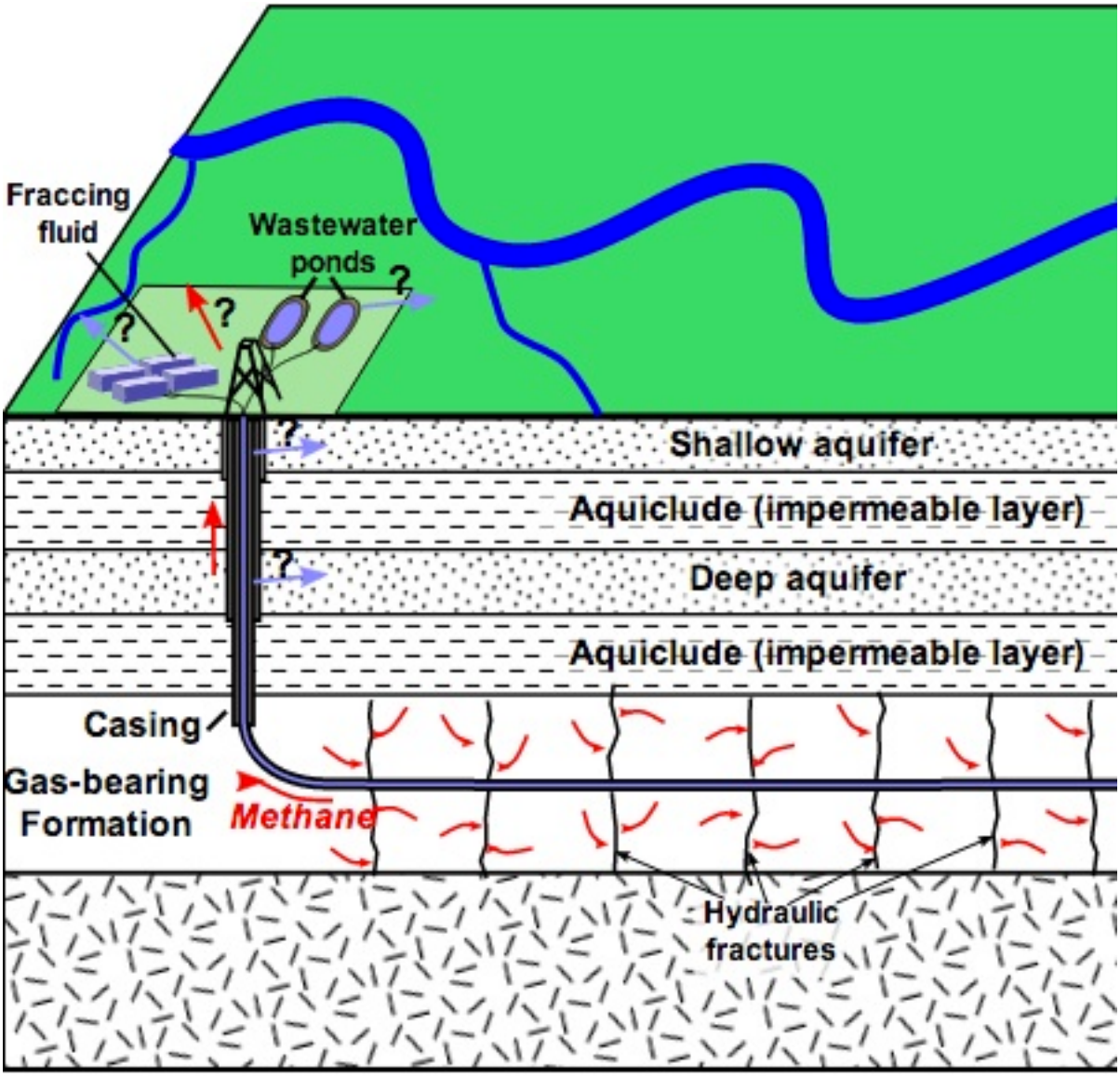
Their analyses, made on water samples collected repeatedly over the course of two years, were even more concerning than we'd feared. As published today in the journal Environmental Science and Technology, they found high concentrations of of the element radium, a highly radioactive substance. The concentrations were roughly 200 times higher than background levels. In addition, amounts of chloride and bromide in the water were two to ten times greater than normal.

"Even if, today, you completely stopped disposal of the wastewater," Vengosh says, there's enough contamination built up that"you'd still end up with a place that the U.S. would consider a radioactive waste site."



The scientists tested wastewater released by the Josephine Water Treatment plant (black square) into Blacklick Creek, which feeds into the Allegheny River, a drinking water source for Pittsburgh. Image via Environmental Science and Technology/Warner et. al.

In recent years, the use of fracking to extract natural gas from shale formations has boomed in several areas, most notably Pennsylvania's Marcellus Shale, which has been called "the Saudi Arabia of natural gas." The process involves injecting mix of water, sand and proprietary chemicals deep into rock at high pressure, causing the rock to fracture and allowing methane gas to seep upward for extraction.



Between 10 and 40 percent of the fluid injected during the fracking process resurfaces, presenting a treatment problem for processing plants. Image via Wikimedia Commons/Mikenorton

Much of the concern over fracking has related to the seepage of these chemicals or methane from drilling wells into groundwater or the fact that high-pressure injection can trigger earthquakes, but the wastewater recently tested presents a separate, largely overlooked problem.

Between 10 and 40 percent of fluid sent down during fracking resurfaces, carrying contaminants with it. Some of these contaminants may be present in the fracking water to begin with. But others are leached into the fracking water from groundwater trapped in the rock it fractures.

Radium, naturally present in the shales that house natural gas, falls into the latter category—as the shale is shattered to extract the gas, groundwater trapped within the shale, rich in concentrations of the radioactive element, is freed and infiltrates the fracking wastewater.

Other states require this wastewater to be pumped back down into underground deposit wells sandwiched between impermeable layers of rock, but because Pennsylvania has few of these cavities, it is the sole state that allows fracking wastewater to be processed by normal wastewater treatment plants and released into rivers.

These plants, many scientists note, are not designed to handle the radioactive elements present in the wastewater. Neither are they required to test their effluent for radioactive elements. As a result, many researchers have suspected that the barely-studied water they release into local streams retains significant levels of radioactivity.

This new work confirms that suspicion for at least one plant—which as about an hour east of Pittsburgh, and releases effluent into the watershed that supplies the city's drinking water—and Vengosh believes that the findings would likely be similar for many of the other facilities in Pennsylvania. Especially concerning is the fact that, apart from in the water, the team found high levels of radioactivity accumulating on the sediments at the bottom of the stream over time. Radium has a half-life of 1600 years, so unless these sediments are removed, they'll keep releasing radiation into the water for an extremely long period.

In addition, the high levels of bromide found in the wastewater is a concern, because even in slight quantities, the compound can trigger the formation of a toxic class of chemicals called halomethanes when it's combined with chlorine. This is a problem because in rural areas, many residents treat well water by chlorinating it.

The study—which is part of a larger Duke project studying the effect of fracking on water—doesn't show that fracking is inherently unsafe, but does show that without proper controls, the wastewater being dumped into the environment daily represents a very real danger for local residents.

Vengosh notes that there are better methods of treating fracking wastewater (he points to the plants operated by Eureka Resources as a model for adequately removing radioactivity), but these are more expensive to operate. But currently, without the push of federal regulations, companies looking to dispose of wastewater have no incentive to pay for this type of solution.

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